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DEVELOPMENT OF TEST METHODS FOR THE ELECTROSTATIC PROPERTIES OF NONHOMOGENEOUS FABRICS: PHASE II

BY
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This report covers Phase II of a project initiated for the purpose of establishing the feasibility of testing for electrostatic charge decay rates, field suppression capabilities, and triboelctric charge generating properties of textiles which incorporate a small percentage of conductive content, and to provide suitable test equipment and test methodology for determining these characteristics in laboratory situations. Commercially available instrumentation was modified and new equipment designed and fabricated as necessary to achieve the desired results. All modifications and the new equipment were thoroughly documented to facilitate possible later duplication with retention of critical parameters. Three test methods, one for each of the above characteristics, were formulated for possible inclusion in FTMS 191. This effort has resulted in the equipment and methodology necessary to determine (a) the percentage of field suppression offered by the conductive content of a fabric, (b) the charge decay rate of the nonconductive content of the same fabric, and (c) the triboelectric charge generating properties of any fabric.

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PREFACE

The October 1984 issue of "Department of Defense Program Solicitation for Small Business Innovation Research No. 85.1" included Army Research Topic No. 83, "Test Methodology and Apparatus for Measurement of Static Electricity in Fabrics" originated by Sharyn L. Seasholtz of the U.S. Army Natick Research, Development and Engineering Center. The stated purpose of the proposed exploratory development effort was to devise suitable test methods and apparatus for the measurement of the electrostatic properties of synthetic fabrics which incorporate a small percentage of highly conductive material. These fabrics are intended for use in the manufacture of uniforms for Combat Vehicle crewmen and aircrewmen to minimize the generation of electrostatic charges.

A background of considerable research into the properties of synthetic clean-room garments containing conductive fibers prompted I.K.E. Associates, Inc. to respond to the solicitation. Government contract No. DAAK60-85-C-0074 was subsequently awarded. Sharyn L. Seasholtz (STRNC-ITC), U.S. Army Natick was appointed Project Officer. Work commenced on Phase I of the project on 1 July 1985.[1]

Existing commercially available test equipments were obtained and modified as necessary to test for the static decay and field suppression properties of the fabrics in question. A triboelectric test apparatus was designed and fabricated to determine the charge generating property of a fabric when rubbed by the same or a different material. The apparatus utilizes the above test equipment to display and record the data obtained. Phase I of the Project was completed on 7 April 1986 with submission of the Phase I Final Report.[1]

Upon completion of Phase I of the Project, a proposal for Phase II was submitted. The proposal was accepted and Phase II authorized by modification of the original contract effective 28 May 1986. Work commenced on Phase II shortly thereafter. This phase was to include further experiments with and debugging of the total system developed during Phase I. Also included was the formulation of three new test methods for future incorporation into Federal Test Method Standard 191. These methods are intended to test for (a) the percentage of E-field suppression offered by the conductive content of a fabric, (b) the charge-decay rate of the relatively nonconductive content and (c) the triboelectric properties of a specimen of fabric when rubbed with another material.

In addition, Phase II includes the documentation of all modifications incorporated into commercial equipments and of all new equipments designed and fabricated during the course of Phase I. This documentation will provide for the future duplication of the overall test system. Further, step-by-step operating procedures for all equipments necessary in the system for each of the three test methods are also included. These procedures include explicit settings for certain peripheral equipments furnished to the government by the contractor.

Phase II was completed for all practical purposes on 21 August 1987 with the delivery to US Army Natick RD&E Center of all equipments either purchased or designed and fabricated under the contract. Also delivered were the Master Drawings containing complete documentation reflecting the fabricated equipment and necessary modifications to those purchased commercial equipments requiring revisions to fulfill the goals of the project. Photographically reduced copies of these drawings are included as Appendix A of this report. In addition, the final drafts of the three test methods were also delivered together with step-by-step procedures to assist testing personnel in performing each of the test methods utilizing the equipments provided as a system.

Anticipating some few changes in the three proposed test methods prior to official publication and the high probability of future revisions, copies of the original proposed test methods are included in this document as Appendices B, C and D. By this means the original documentation will be preserved for reference purposes as being of historical significance. New revisions can thus be compared with the originals to avoid changes that might inadvertently subvert the basic intent of the test methods.

I.K.E. Associates would like to thank the following firms for their rapid response and cooperation in solving equipment problems that occurred during the course of this project.

Electro-Tech Systems, Inc.
Glenside, PA 19038

BBC-Metrawatt/Goerz
Broomfield, CO 80020

Solomat Corporation
Stamford, CT 06906

TABLE OF CONTENTS

DEVELOPMENT OF TEST METHODS FOR THE ELECTROSTATIC PROPERTIES OF NONHOMOGENEOUS FABRICS: PHASE II

1. BACKGROUND:

The hazard presented by an electrostatic discharge in an explosive environment has been well known for many years. The prevalence of highly (electrically) insulative synthetics in garments and other commonly used items has increased the incidence of such discharges to unprecedented proportions. The problem has expanded from explosive hazards into the world of microelectronics where sensitive devices can experience catastrophic damage from discharges so small in amplitude as to be undetectable by normal human senses. Moreover, a static charge residing on the surface of a highly insulative material can induce a charge on nearby conductive items. This phenomenon has been known to initiate explosions without the need for an actual discharge by actuating electrical squib-type firing devices with fatal results.

The problems are of such magnitude that they have resulted in the establishment of an entirely new industry, that of designing and supplying materials and equipment for the specific purpose of controlling the generation of static charges, or of minimizing their harmful effects. The proliferation of special materials in a myriad of forms has far outstripped the generation of test methods suitable for determining their ability to perform as intended. As a result, the manufacturers and/or purveyors of these items rely to a great extent on a very few already existing test methods as references to describe the electrical characteristics of the materials in question. In many instances, the test methods referenced were never designed to test that particular material (or form) and it remains a mystery how the published data was obtained.

One such family of specialized materials is a new type of textile that incorporates conductive carbon or metal filaments in various patterns and percentages. These textiles are intended for use in the manufacture of garments to be worn in explosive environments such as hospital operating rooms and munitions handling situations, and in areas where microelectronic devices are being fabricated. These unique fabrics are intended to furnish two forms of electrostatic protection:

(a) The conductive filaments provide an extremely low resistance path between all areas of the garment to speed the distribution of generated charges over the entire garment thereby greatly lowering the charge amplitude, and if grounded, to bleed off a charge entirely--more rapidly than it can accumulate. This property is somewhat dependent on any inherent conductivity of the relatively nonconductive content of the fabric which may completely surround the conductive filaments.

(b) These same filaments (when grounded) provide a shielding effect, which suppresses any voltage fields emanating from charges that may be present on garments worn beneath. This shielding effect, although extremely desirable, has the distinct disadvantage of confusing the results of any tests performed in accordance with existing standardized test methods. It is necessary, therefore, to either devise new test methods for these fabrics or to modify existing test methods to the extent that they are usable for the electrical characterization of the materials in question. Thus, appropriate accept/reject criteria can be established.

2. INTRODUCTION:

Phase I of this project was initiated on 1 July 1985 under Contract Number DAAK60-85-C-0074 and completed on 7 April of the following year.[1] It established the feasibility of testing for the charge decay rates, electrostatic field-suppression capabilities, and triboelectric charge generating properties of a variety of textiles containing small percentages of highly conductive material evenly distributed throughout the fabric.

During the above feasibility study, commercially available test equipment was modified where necessary in order to obtain data that the equipment had not been designed to provide. A Triboelectric Test Fixture capable of establishing the peak value of electrostatic charge which could be generated on a specimen when rubbed by the same or by another selected material was also designed and fabricated. Phase II of the project consisting of necessary documentation of test equipment, the writing of the three proposed test methods, and the formulation of step-by-step procedures for equipment operation was commenced on 1 June 1986.

3. TEST EQUIPMENT:

The following test equipment was either acquired from commercial sources or designed and fabricated for use in the performance of the three proposed test methods during the course of the project. A brief description of each is included together with modifications incorporated into certain of the commercial equipments.

(a) Electro-Tech Systems, Inc. (ETS) Model 506 Controlled Humidity Test Chamber. This glove-box type test chamber was modified by installing a system of hermetically sealed electrical feed-thru connectors to improve hermeticity. The circulating air drier system is now capable of lowering the internal atmosphere of the chamber to less than 1% relative humidity and maintaining it at that level for long periods of time.

(b) <u>ETS Model 406C Static Decay Meter</u>. Originally designed specifically to test materials in accordance with FTMS 101, Method 4046,[2] this instrument was modified to provide for operator selectable inhibition of the three-minute cutoff and/or percentage level timeout features of the instrument. Special circuitry was also installed to allow selectable four-, six- and nine-second automatic E-field detector probe "zero" cycling.

An inverting amplifier was installed to cause the recorder output to be of the same polarity as the front-panel sample charge meter. A trigger output was provided at the rear panel for initiation of a recording device just prior to activation of the discharge relay.

Modifications to the decay-time test fixture included improvements to the specimen mounting plate and repositioning the sensor probe to maximize the percentage of specimen E-field suppression that could be detected. Charge and discharge relays were repositioned from the instrument to the test fixture to improve accuracy of measurements. The test fixture was also modified to allow decay time measurements of completed garments in accordance with a new test method for this purpose (EOS/ESD-S2)[3] recently developed by the EOS/ESD Association, further broadening the capabilities of the instrument.

(c) <u>BBC-Metrawatt/Goerz (BBC) Model SE-561 Memory Chart Recorder</u>. This extremely sophisticated instrument replaces the BBC Model SE-120 Chart Recorder originally purchased under the contract. This state-of-the-art instrument was introduced into the marketplace well after the commencement of Phase I of this project.

(d) <u>BBC Model M-2050 Digital Scope-Multimeter (with memory)</u>. Originally purchased to supplement the Model SE-120 mentioned above, this instrument was retained under the contract to provide accurate signal measurements and for purposes of previewing recorder inputs prior to actually recording signals on chart paper.

(e) <u>Solomat Corporation Model MPM 500 Thermo Hygro Tachometer</u>. This instrument was purchased to provide an accurate measurement of the internal environment of the test chamber. Recent developments at Electro-Tech systems have made available a highly accurate automatic humidity control system designed to operate in conjunction with the Model 506 Humidity Chamber. This system became available too late to be included in the contract, but is highly recommended as a future improvement to the overall test system under discussion.

(f) Triboelectric Test Fixture. This apparatus was designed and fabricated under the contract to operate in conjunction with (b) and (c) above and fits easily into the test chamber. A small but powerful synchronous AC gearmotor with an output speed of exactly 100 RPM rotates a Polytetrafluoroethylene (PTFE) rubbing wheel. The specimen is mounted between two metal plates, each of which incorporates a circular opening across which the specimen is stretched during the mounting procedure. Ten of these specimen holders were included to facilitate the simultaneous conditioning of a number of specimens within the chamber.

A separate control console is provided to furnish the appropriate timing signals to the test fixture and a trigger to initiate the recording device. Other circuitry is also present in this console which was originally used for various purposes during Phase I of the project. Later developments proved that these provisions were not necessary to the final version of the test procedure. These circuits were left intact since they do not interfere with normal operation of the equipment and may find a use in the future.

It should be noted that all necessary circuitry currently located in the test console could be contained within the chassis of the test fixture, and that in all probability such will be the case in the next generation of this apparatus. This can be easily accomplished without destroying repeatability of test results between equipments so long as certain critical dimensions are not altered.

A calibration module designed to substitute in the specimen holder position is furnished. When in use the "target" surface of this module is automatically positioned at the exact location normally occupied by a test specimen. Connecting 5,000 V DC obtained from the 406C to this module while installed in the test fixture allows the entire system to be calibrated accurately and for a maximum specimen or wheel charge measurement of 25,000 volts.

After a specimen has been mounted in a holder and conditioned, the holder (with specimen) is manually inserted between two slotted insulators. A momentary (RUN) switch is then pressed to initiate the timing sequence and trigger the recording device. This action causes a solenoid to operate, positioning the rotating wheel against the specimen. The wheel remains in that position for a fixed 10-second interval and is then automatically drawn back to its original position. The operator then removes the specimen holder and again presses the RUN switch. The wheel returns to the rubbing position with no specimen in place for a second 10-second interval and then automatically withdraws. During this entire sequence the E-field probe is measuring detected fields and delivering the resulting signals to the recording device via the 406C.

By proper prior adjustment of the time length of the recording ($\approx$ 30 seconds), all detected signals can thus be charted for the entire sequence. Probe signals recorded from the specimen are (1) the rubbing time and (2) the specimen charge after the wheel is withdrawn. This is followed by a third signal representing the residual charge remaining on the rubbing surface of the wheel after its return to the rubbing position with no specimen in place.

This latter signal is of primary importance due to the fact that any conductivity inherent in the specimen will allow its charge to distribute to the metal specimen holder, perhaps more rapidly than the instrumentation can respond. The charge on the highly insulative surface of the wheel, however, is completely immobile and therefore must remain stationary (static) providing a direct indication of what the peak charge on the specimen was, although of opposite polarity.

Since the friction of the rubbing action tends to cause the wheel surface to gather material from the specimen, the wheel surface should be cleaned with trichloroethylene and allowed to dry prior to initiating each test sequence. Failure to do this is sometimes evidenced by a reversal of charge polarity when the surface of the wheel essentially becomes the same material as the specimen and is therefore located at the same position on the "Triboelectric Series" (see Table 1). Cleaning with the solvent also serves to remove the previous residual charge from the wheel. It may also be advisable to thoroughly clean the specimen slides and the specimen stop with this same solvent prior to each series of tests to maintain their insulative properties.

4. TEST EQUIPMENT DOCUMENTATION:

Equipments designed and fabricated for this project and modifications to commercial test equipments purchased under the contract are documented in U.S. Army Natick RD&E Center Drawings 81337-X4-5-100 thru -126 (see Appendix A).

(a) Triboelectric Test Fixture. This item is documented in drawings X4-5-100 thru -117 (pgs. A-2 thru A-23) with the wiring diagram for the fixture's chassis being X4-5-116 (pg. A-22), and its Sensor Head mechanical modification detailed in X4-5-117 (pg. A-23) as an "Altered Item Drawing".

(b) Triboelectric Test Control Console. The schematic diagram for this unit is documented in drawing X4-5-118 (pg. A-24).

(c) ETS Model 406C. Modifications to the specific instrument bearing serial number SDM-406C-0318 and its associated decay-time test fixture are documented in drawings X4-5-120 thru -126 (pgs. A-26 thru A-32). Modifications to the internal circuitry of the instrument are depicted in drawing X4-5-120 (pg. A-26) while the modified schematics for the Test Fixture and the Sensor Head are X4-5-122 (pg. A-28) and -126 (pg. A-32), respectively.

TABLE 1. SAMPLE TRIBOELECTRIC SERIES

A substance higher on the list is positively charged when rubbed with a substance lower on the list due to the fact that the higher substances have more free electrons than the lower substances. Electrons from the higher substance are therefore transferred to the lower substance, giving the latter a negative charge. The distance of separation of the two substances in the listing has no relationship to the amplitude of charges generated.

POSITIVE (+)	AIR
	HUMAN HANDS
	ASBESTOS
	RABBIT FUR
	GLASS
	MICA
	HUMAN HAIR
	NYLON
	WOOL
	FUR
	LEAD
	SILK
	ALUMINUM
	PAPER
	COTTON
	STEEL
	WOOD
	AMBER
	SEALING WAX
	HARD RUBBER
	NICKEL, COPPER
	BRASS, SILVER
	GOLD, PLATINUM
	SULFUR
	ACETATE RAYON
	POLYESTER
	CELLULOID
	ORLON
	POLYURETHANE
	POLYETHYLENE
	POLYPROPYLENE
	PVC (VINYL)
	KEL F
	SILICON
NEGATIVE (-)	PTFE

(d) Complete Test System Interface. All equipment electrical interconnections necessary for performing each of the three proposed test methods are depicted in drawing X4-5-119 (pg. A-25).

5. TEST METHODS:

The final versions of the three test methods are essentially the same as those described in the Phase I final report[1] with a number of changes in the interests of simplicity and efficiency brought about by experiments performed in the course of Phase II of the project.

(a) Field Suppression Test Method. This test method (see Appendix B) has no significant changes. It is merely necessary to first ascertain on a one-time basis the minimum percentage of suppression the particular test system being used is capable of detecting. The time-base of the recording device is then adjusted such that the transition from a sudden drop in signal to a much slower decaying curve as detected from the specimen E-field is clearly discernible on the recording media. The percentage of field suppression can then be readily calculated from the chart. No specimen conditioning is necessary since the field-suppression characteristic of the specimen is not affected by changes in the RH level.

(b) Decay Time Test Method. This test method (see Appendix C) has been finalized to provide for a simpler and more repeatable method of calculation of decay rates. Rather than utilize the formula for Tau (τ) described in the Phase I final report,[1] the $^1/e$ factor of $\approx 36.8\%$ is utilized. Once the transitition point from field suppression is determined for a particular specimen, the Y-axis sensitivity of the recording device is then increased for a second recording such that the known transition point is near (but not beyond) the maximum limit of the recording media.

At the same time, the X-axis of the recording device is adjusted to include in the recording that portion of the curve wherein the signal decays from the transition point to at least 36.8% of that value. After the second recording is made, the chart is then analyzed to determine the time required for the signal to decay from the transition point to 36.8% of that value, this time-lapse being the τ of the specimen.

In the event specimens of several different fabrics are to be tested in the same series for comparison purposes, it would be well to first determine the transition points for the entire group. The lowest value of all transition points would then be utilized for calculating the 36.8% point of all specimens, thus partially overcoming the problem of non-ohmic resistivity inherent in certain synthetics. Calculations for all specimens in the series would thus commence at the same charge level. By this means the "decay rates" of the relatively nonconductive content of the specimens could be more accurately compared.

(c) Triboelectric Test Method. This test method (see Appendix D) has been considerably modified from the original concept. Rather than observe only the charge generated on the specimen itself, the final version calls for recording the charge signals generated by an entire sequence including (a) the charge detected on the specimen during rubbing time, (b) the charge present on the specimen during wheel retraction and for a short period thereafter, and (c) the residual charge remaining on the wheel after the specimen is removed and the wheel has been returned to the rubbing position with no specimen in place.

The charge on the specimen will be at its peak as the wheel is withdrawn. Since any conductivity in the specimen will cause this charge to distribute to the metal specimen holder thus loading up its capacitance, the detected specimen charge will appear as an apparent decaying exponential whose rate of decay is dependent on the conductivity of the specimen. This decay rate could easily be so rapid as to be beyond the response capability of the instrumentation and the actual peak specimen charge therefore not be recorded.

Since triboelectric charging is caused by contact and separation of two different objects, and results from an exchange of electrons, it follows that one of the two interacting objects will gain electrons while the other will lose an equal quantity. The direction of electron movement is dependent on the relative positions of the two objects on the "Triboelectric Series" (see Table 1). An item higher in the series will lose electrons and gain a positive charge when interacting with an item lower in the series , which thus acquires a negative charge. In the event both items are identical materials, the polarities could be in either direction but always opposite. The distance of separation between the positions of the two items on a "Triboelectric Series" has no relationship to the amplitude of the charges generated.

The rubbing surface of the wheel is PTFE, a material located at the extreme lower end of the triboelectric series. Therefore almost any material other than PTFE rubbed by the wheel will gain a positive charge, while the surface of the wheel will become negatively charged to an equal amplitude. Due to the highly insulative nature of the wheel's rubbing surface, this negative charge must remain stationary (static) for a lengthy period of time possibly determined by the quantity of positive ions available in the surrounding atmosphere. These phenomena allow the residual charge on the wheel's rubbing surface to be measured as representative of the peak charge actually attained on the specimen even though it might for some reason be impossible to record the peak specimen charge directly. The wheel charge will normally be negative while the specimen charge will be positive in polarity.

Differences in wheel charge amplitudes between various specimens will be entirely dependent on characteristics inherent in individual specimens at the time testing is performed provided that the wheel is cleaned prior to commencement of each test. These characteristics could be due to natural lubricity, texture, moisture, some chemical additive, or combinations thereof.

Adjustment of the Y-axis of the recording device to position the "0" signal at center-scale allows both positive and negative polarities of detected signals to be recorded. Automatic triggering of the recorder at initiation of rubbing time, together with appropriate settings of time-base and recording length, results in a comprehensive illustration of all signals detected during an entire test sequence (see Appendix D illustrations).

(d) Completed-garment Decay-time Test Method. Provisions for testing personnel garments in accordance with EOS/ESD-S2[8] were included in the modifications to the ETS 406C Test Fixture as depicted on drawing #X4-5-122 (see pg. A-28). This modification consists of an additional HV relay which routes the normal specimen charge/discharge path through two HV Jacks conveniently located in one side of the fixture chassis. A toggle switch on the top of the chassis enables this circuit. Two clamp electrodes fabricated in accordance with the test method and fitted with appropriate HV leads and plugs are provided.

It is merely necessary to connect the test fixture to the 406C in the normal fashion. A metal plate or sheet of foil is substituted for the specimen in the test fixture and the "Garment/Normal" toggle switch placed in the GARMENT position. The garment is then suspended from the two clamp electrodes in accordance with the test method. One electrode is then connected to each of the HV Jacks on the test fixture, and the 406C set for manual operation on its front panel. With the 406C high voltage adjusted to the specified charge voltage, proceed as for normal specimen decay-time testing.

The clamping electrodes currently specified in the test method are thought to provide less than adequate electrical contact with garments being tested. However, since the test method is not yet finalized, the possibility exists that problems with these items may be corrected in the near future. In all probability the basic test method will remain unchanged, and the test fixture itself, as currently modified, will more than adequately serve the purpose.

6. STEP-BY-STEP EQUIPMENT OPERATING PROCEDURES:

A complete step-by-step operating procedure for each of the three proposed test methods included as Appendices B, C and D of this report was formulated and delivered to the contracting facility. The procedures cover the interconnection, calibration and operation of all necessary equipment and instrumentation furnished under the contract. Intended only to serve as guidelines prior to acquired operator proficiency, these procedures are not included as a part of this report.

7. PROJECT RESULTS:

All the proposed objectives of the project have been met as follows:

(a) The feasibility of testing fabrics containing small percentages of highly conductive material for field-suppression, charge decay rates, and triboelectric charge generation characteristics has been proven. Since the charge decay rate of a material is always directly related to its resistivity (or conductivity), and the presence of conductors within an otherwise highly resistive fabric seriously confuses direct measurements of resistivity, the proposed charge decay test method (see Appendix C) can be substituted for FTMS 191, Method 5930[4] and ASTM D257[5] in certain situations where neither is satisfactory.

(b) Commercial test equipment has been acquired and modified as necessary to provide for performing the proposed test methods without impairing the designed purposes of the equipment.

(c) A Triboelectric Test Apparatus has been designed and fabricated for purposes of testing fabrics and other flexible materials for their triboelectric charge-generating properties.

(d) The equipment modifications and apparatus of (b) and (c) above have been thoroughly documented in the form of military drawings and can therefore be easily duplicated.

(e) The three proposed Test Methods have been formulated for prospective inclusion in Federal Test Method Standard No. 191.

(f) Three separate step-by-step procedures have been formulated to serve as guidelines in the use of the delivered equipments in performing the proposed test methods.

This document reports research undertaken in cooperation with the US Army Natick Research, Development and Engineering Center under Contract No. DAAK60-85-C-0074 and has been assigned No. NATICK/TR-88/010 in the series of reports approved for publication.

LIST OF REFERENCES

1. B. I. Rupe, "Development of Test Methods for the Electrostatic Properties of Nonhomogeneous Fabrics: Phase I," Contract No. DAAK60-85-C-0074 with I.K.E. Associates, Inc., NATICK/TR-86/056 (AD A177 026)

2. Federal Test Method Standard No. 101, Method 4046: "Electrostatic Properties of Materials"

3. EOS/ESD Standard No. 2 (EOS/ESD-S2): "Standard for Protection of Electrostatic Discharge Susceptible Items: Personnel Garments"

4. Federal Test Method Standard No. 191, Method 5930: "Determination of Electrical Resistivity in Fabrics"

5. American Society for Testing and Materials (ASTM) D 257: " Standard Methods of Test for D-C Resistance or Conductance of Insulating Materials"

INDEX OF APPENDICES

APPENDIX A

This appendix consists of reproductions of the original Master Drawings submitted to U S Army Natick Research, Development and Engineering Center by I.K.E. Associates, Inc. under Contract No. DAAK60-85-C-0074. The drawings have been photographically reduced in size to allow insertion into this report. Entry has been made in numerical order with no ommissions commencing with X4-5-100 on page 14 and ending with X4-5-126 on page 44.

NOTES

1. SUBSTITUTE ITEM 15 FOR ITEM 14 WITH MACHINED SIDE FACING SENSOR HEAD DURING CALIBRATION PROCEDURES.
2. MARK WITH METAL STAMPS IN .250 HIGH LETTERS. FILL WITH BLACK PAINT.
3. SUGGESTED SOURCE(S) OF SUPPLY:
   IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).

   ELECTRO TECH SYSTEMS, INC. (CODE IDENT. NO. 56540)
   115 EAST GLENSIDE AVENUE
   GLENSIDE, PA 19038

   PART NUMBER: MODEL 407

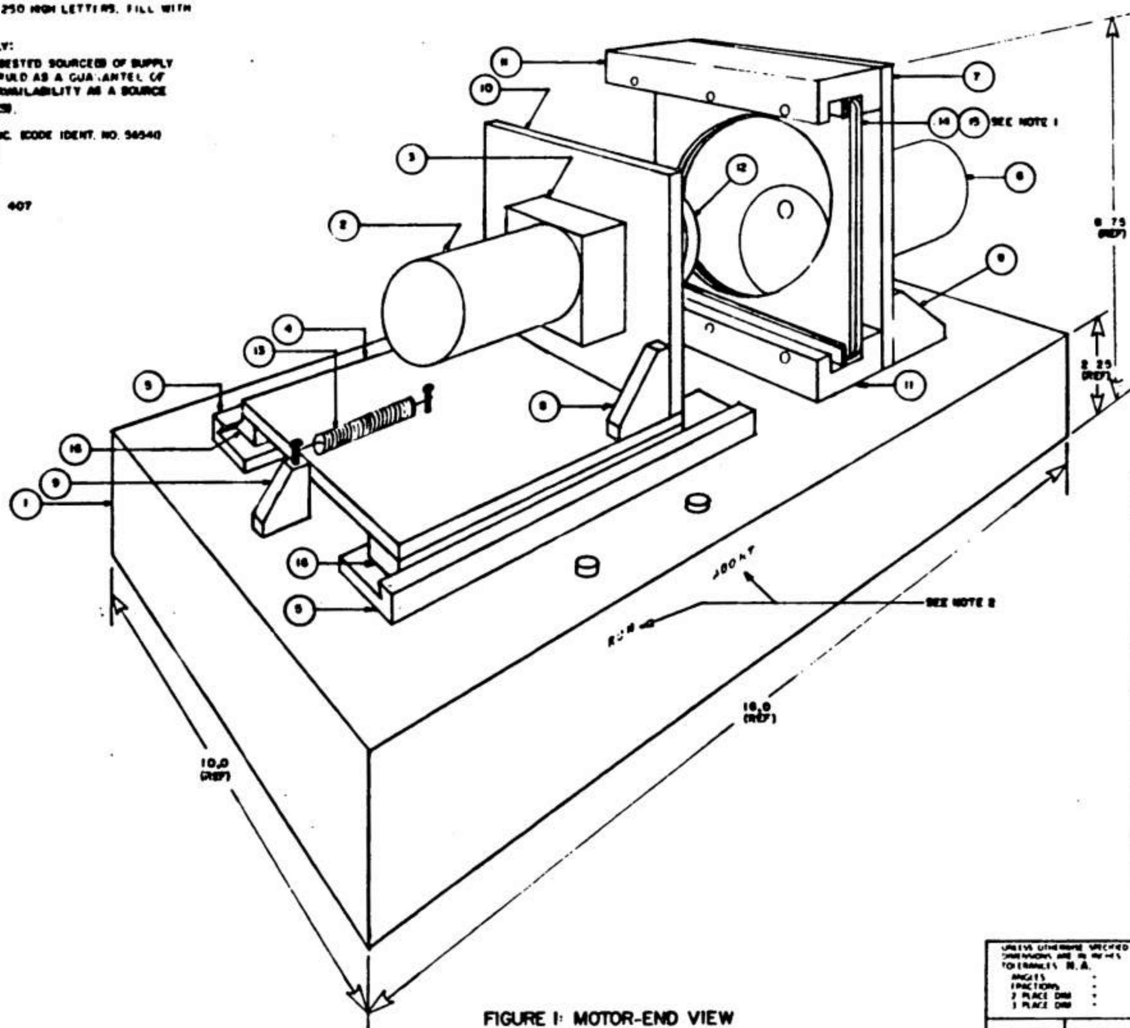


FIGURE I: MOTOR-END VIEW

ITEM OR FIND NO	QTY REQD.	CAGE NO.	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
16	2	81337	4-5-110	SLIDE, MOTOR PLATFORM
15	1	81337	4-5-107	PLATE, CALIBRATION
14	10	81337	4-5-106	SPECIMEN FRAME ASSY
13	1			SPRING, MOTOR RETURN
12	1	81337	4-5-114	RUBBING WHEEL ASSY.
11	2	81337	4-5-113	SLIDE ASSY, SPECIMEN FRAME
10	1	81337	4-5-108	MOUNTING PLATE, MOTOR
9	1	81337	4-5-112	STOP, MOTOR RETURN
8	4	81337	4-5-109	BRACE, REINFORCING
7	1	81337	4-5-103	MOUNTING PLATE, SENSOR
6	1	81337	4-5-117	SENSOR HEAD ASSY
5	2	81337	4-5-104	SLIDE, CHASSIS
4	1	81337	4-5-105	PLATFORM, MOTOR
3	1	77220	2GN18KA	REDUCTION GEAR
2	1	77220	2SK40A-AA	MOTOR
1	1	81337	4-5-101	CHASSIS

PARTS LIST

D X4-5-100 1 of 4

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES N.A.
ANGLES ±
FRACTIONS ±
2 PLACE DIM ±
3 PLACE DIM ±

4-5-119
NEXT ASSY | USED ON
APPLICATION

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I. K. E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46250
DATE 7/18/87
DRAWN BY Rasa
CHECKED
PROJ OFCR
APPROVED
APPROVAL DESIGN ACTIVITY
APPLICABLE SPEC

U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK, MA 01760

TEST FIXTURE ASSEMBLY, TRIBOELECTRIC

SIZE D | CAGE NO 81337 | DRAWING NO X4-5-100
SCALE NONE | UNIT WT | SHEET 1 OF 4

NOTES

4. CABLE MOTOR LEADS TO ITEM 21 WITH 6 TO 7 INCHES TOTAL LENGTH. SEE DWG NO 81337- 4-5-118 FOR TERMINAL CONNECTIONS

5. MAKE TEST FIXTURE CONTROL CABLE FROM BENDIX 20 AWG 8 CONDUCTOR, PART NO. 3455 OR EQUAL 8 CONDUCTOR CABLE. LEAVE 18 TO 20 INCHES TOTAL LENGTH OUTSIDE CHASSIS. IN THE EVENT TEST FIXTURE IS FOR USE IN CHAMBER HAVING NO FEED-THRU CONNECTOR, MAKE CABLE 48 TO 60 INCHES LONG.

6. ITEM 18 NORMALLY PROVIDED AS PART OF ITEM 6. MODIFICATIONS TO SENSOR HEAD (ITEM 6) ARE LISTED ON DWG. NO. 81337- 4-5-117.

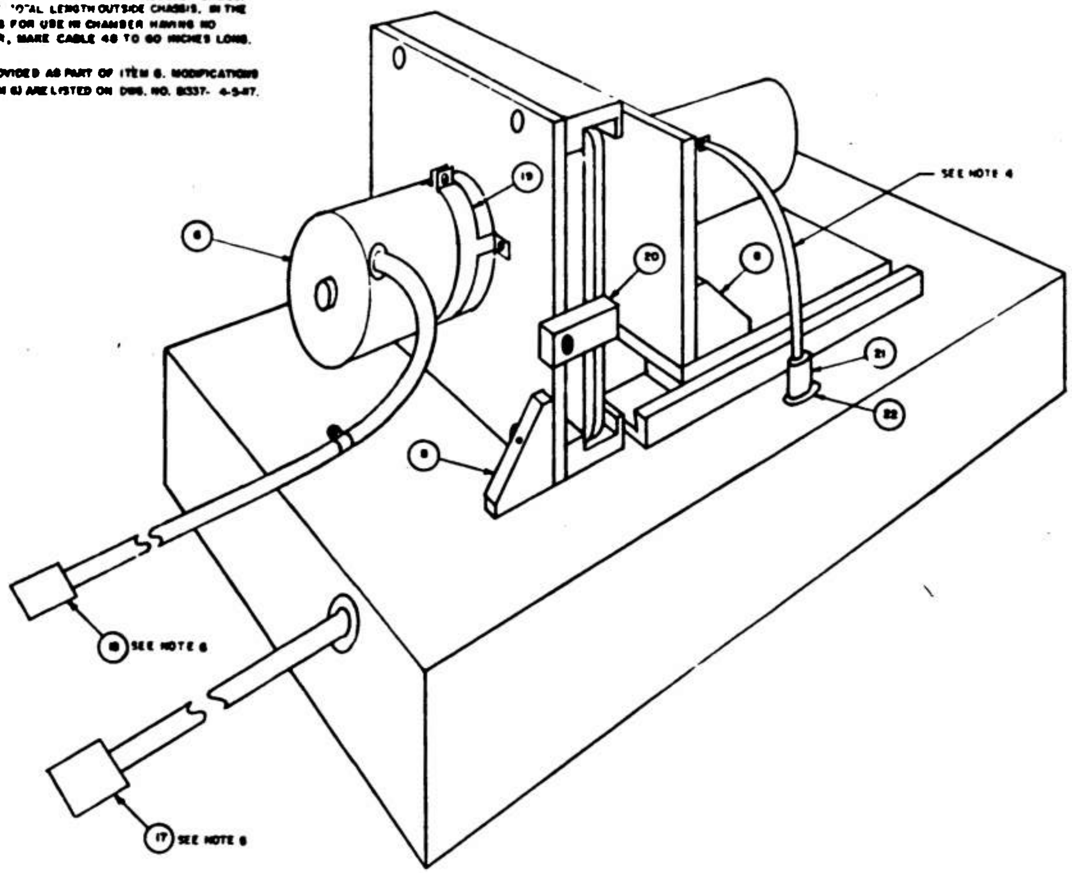


FIGURE 2: CABLE-END VIEW

ITEM OR FIND NO.	QTY. REQD.	CAGE NO.	PART NUMBER OR IDENT. NO.	NOMENCLATURE OR DESCRIPTION
22	1			CONNECTOR, [illegible]
21	1			CONNECTOR, [illegible]
20	1	81337	4-5-113	[illegible]
19	1	[illegible]	[illegible]	BRACKET, MOUNTING
18	1		[illegible]	CONNECTOR, PLUG, 7 PIN
17	1		[illegible]	CONNECTOR, PLUG, 8 PIN

PARTS LIST

U.K.E. ASSOCIATES, INC.

U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER

TEST FIXTURE ASSEMBLY, TRIBOELECTRIC

SIZE D | CAGE NO 81337 | DRAWING NO X4-5-100

D X4-5-100

A-3

NOTES

7 SEE DWG NO 81337- 4-5-116 FOR ELECTRICAL CONNECTIONS.

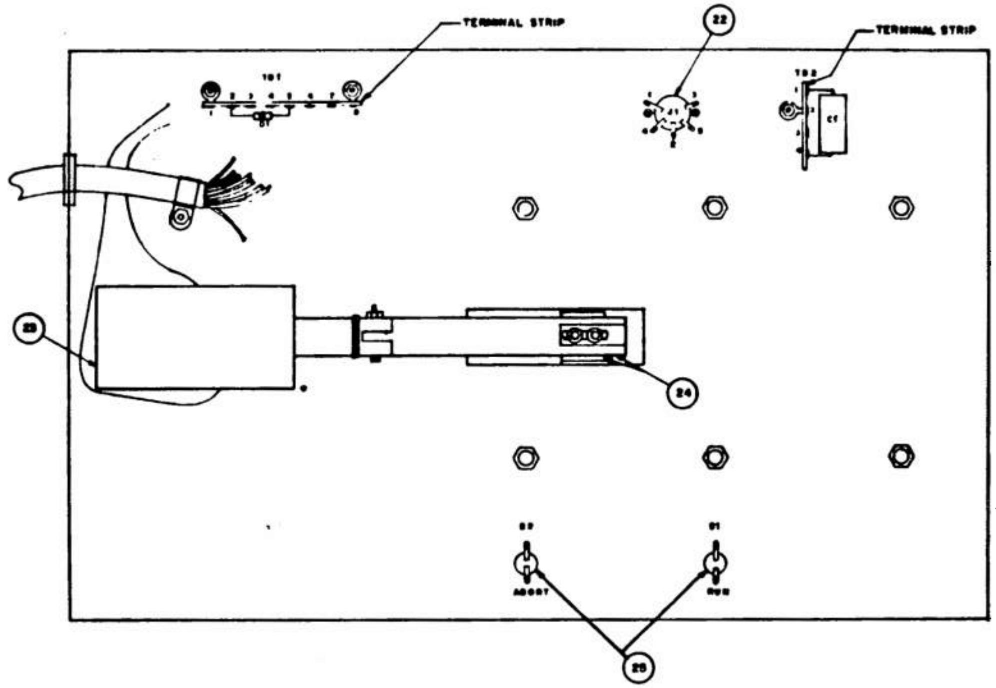


FIGURE 3: CHASSIS INTERNAL PARTS LOCATIONS

ITEM OR FIND NO	QTY. REQD.	CAGE NO.	PART NUMBER OR I.D. NO.	NOMENCLATURE OR DESCRIPTION
[illegible]	2	[illegible]	[illegible]	SWITCH, [illegible]
[illegible]	1	[illegible]	4-2-111	[illegible] SOLENOID
[illegible]	1	[illegible]	[illegible]	SOLENOID, [illegible], 24 VDC

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES N.A. ANGLES: FRACTIONS: 2 PLACE DEC: 3 PLACE DEC:	IRE ASSOCIATES, INC. INDIANAPOLIS, IN 46250 DATE [illegible] DRAWN BY [illegible] CHECKED PROJ OFCR APPROVED APPROVAL DESIGN ACTIVITY	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760
4-6-110 USED ON / NEXT ASSY / APPLICATION	APPLICABLE SPEC	TEST FIXTURE ASSEMBLY, TRIBOELECTRIC
INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100		SIZE D CAGE NO 81337 DRAWING NO X 4-5-100 SCALE NONE UNIT WT SHEET 3 OF 4

D X4-5-100 3 of 4

NOTES

8. ASSEMBLE TEST FIXTURE IN SEQUENCE AS STATED IN THE FOLLOWING STEPS:

A. SECURE FRAME OF SOLENOID (ITEM 23) TO UNDERSIDE OF CHASSIS (ITEM 1) AT LOCATION INDICATED IN FIGURE 3. USE SIX (6) 6-32 NC X .25 PAN-HEAD SCREWS. (WARNING LONGER SCREWS MAY DAMAGE SOLENOID COIL.)

B. SECURE TWO (2) CHASSIS SLIDES (ITEM 5) TO UPPER SURFACE OF CHASSIS IN POSITIONS INDICATED IN FIGURE 1. USE SIX (6) EA. .250-20NC X .75 FLAT-HEAD SCREWS AND HEX NUTS.

C. INSTALL TWO (2) EA. MOMENTARY SWITCHES (ITEM 25) AND ONE (1) DIN SOCKET (ITEM 22) AT LOCATIONS INDICATED ON FIGURE 3 USING HARDWARE AS NECESSARY.

D. PROVIDE AND INSTALL TERMINAL STRIPS AT TWO LOCATIONS INDICATED ON FIGURE 3.

E. INSTALL CONTROL CABLE DESCRIBED IN NOTE 9 AS INDICATED ON FIGURE 3. USE RUBBER GROMMET AT CHASSIS WALL AND STRAIN-RELIEF CABLE CLAMP AS INDICATED.

F. ACCOMPLISH ALL INTERNAL CHASSIS WIRING IN ACCORDANCE WITH DWG NO. 81337- 4-5-115. INSTALL CAPACITOR C1 AND DIODE D1 AS INDICATED ON FIGURE 3. OBSERVE CORRECT POLARITY FOR D1.

G. INSTALL SENSOR MOUNTING PLATE (ITEM 7) AT LOCATION INDICATED IN FIGURE 2 USING TWO (2) 6-32 NC X .50 SOCKET-HEAD CAP SCREWS. INSTALL TWO (2) REINFORCING BRACES (ITEM 8) AT LOWER CORNERS OF ITEM 7. SECURE BRACES TO CHASSIS AND TO ITEM 7 WITH EIGHT (8) 6-32 NC X .50 SOCKET-HEAD CAP SCREWS.

H. INSTALL TWO (2) SPECIMEN FRAME SLIDE ASSEMBLIES (ITEM 19) IN POSITIONS INDICATED ON FIGURE 1 USING FOUR (4) .250-20NC X .50 SOCKET-HEAD CAP SCREWS THRU ITEM 7.

I. ASSEMBLE MOTOR MOUNTING PLATE (ITEM 10) TO MOTOR PLATFORM (ITEM 4) BRACING WITH TWO (2) BRACES (ITEM 8) AS SHOWN IN FIGURE 1. USE TEN (10) 6-32 NC X .50 SOCKET-HEAD CAP SCREWS.

J. ASSEMBLE TWO (2) MOTOR PLATFORM SLIDES (ITEM 18) TO THE LOWER SURFACE OF ITEM 4 IN THE POSITIONS INDICATED ON FIGURE 1. USE SIX (6) 10-32 NF X .75 FLAT-HEAD SCREWS.

K. INSERT THE ABOVE ASSEMBLY (STEPS I, J) INTO THE CHASSIS SLIDES (STEP B). ASSEMBLY SHOULD MOVE FREELY ON THE SLIDES WITH NO EVIDENCE OF BINDING WHILE POSSIBLE LATERAL AND VERTICAL MOVEMENT IS MINIMAL. ADJUST POSITIONS OF CHASSIS SLIDES SLIGHTLY IF NECESSARY TO OBTAIN THIS RESULT.

L. REMOVE PLUNGER FROM SOLENOID (ITEM 23) AND ATTACH TO CONNECTING ROD (ITEM 34, FIG. 1), TONGUE IN SLOT. SECURE WITH 6-32 NC X .75 SOCKET-HD CAP SCREW AND NUT TO FIT. A RIGID ASSEMBLY IS NOT EXPECTED OR REQUIRED.

M. WITH O-RING IN PLACE ON PLUNGER, INSERT PLUNGER INTO BODY OF SOLENOID. PLACE PULL BLOCK (ITEM 34, FIG.2) BETWEEN CONNECTING ROD AND MOTOR PLATFORM WITH BLOCK EXTENDING THRU RECTANGULAR OPENING IN CHASSIS, WITH ROUND SURFACE OF ROD RESTING IN CONCAVE END OF BLOCK, SECURE TO MOTOR PLATFORM USING TWO (2) .250-20NC X 2.25 SOCKET-HD CAP SCREWS INSERTED THRU THE SLOT IN THE ROD, THE HOLES IN THE BLOCK, AND INTO THE APPROPRIATE THREADED HOLES IN THE MOTOR PLATFORM. SCREW-HEADS MUST BEAR ON FLATTED SURFACE OF ROD.

N. MOUNT MOTOR RETURN STOP (ITEM 6) ON CHASSIS IN POSITION INDICATED ON FIGURE 1. USE TWO (2) 6-32 NC X .50 SOCKET-HD CAP SCREWS.

O. CONNECT ELECTRICAL LEADS OF MOTOR (ITEM 2) TO DIN PLUG (ITEM 31). ALLOW 6 TO 7 INCHES TOTAL LENGTH OF RESULTING CABLE. REFER TO DWG NO. 81337- 4-5-115 FOR PROPER CONNECTIONS.

P. ASSEMBLE MOTOR AND REDUCTION GEAR (ITEM 3) TO MOTOR MOUNTING PLATE USING FOUR (4) 6-32 NC X 1.75 SOCKET-HD CAP SCREWS. POSITION MOTOR WITH CABLE EXIT ORIENTED AS SHOWN IN FIGURE 3. INSERT MOTOR CONNECTOR INTO DIN SOCKET (ITEM 22).

Q. ASSEMBLE RUBBING WHEEL (ITEM 12) TO MOTOR SHAFT ALIGNING SET-SCREW HOLE WITH FLAT ON SHAFT. WITH SHAFT INSERTED TO MAXIMUM DEPTH IN HUB, SECURE IN PLACE WITH .250-20NC X .25 HEX-DRIVE SET-SCREW.

R. WITH SOLENOID PLUNGER HELD AT ITS MAXIMUM DEPTH WITHIN THE COIL, ADJUST WHEEL RUBBING LOCATION BY VARYING THE POSITIONS OF THE TWO CAP SCREWS IN THE SLOT OF THE CONNECTING ROD (SEE STEP M). SET SPACING BETWEEN SENSOR MOUNTING PLATE AND NEAR EDGE OF RUBBING WHEEL TO .75 ±.05.

S. ATTACH MOUNTING BRACKET (ITEM 16) TO SENSOR MOUNTING PLATE, POSITIONING AS SHOWN IN FIGURE 2. USE THREE (3) 6-32 NC X .25 RND-HD SCREWS.

T. INSERT SENSOR HEAD (ITEM 6) THRU MOUNTING BRACKET INTO MOUNTING PLATE. WITH SENSOR ORIFICE IN ITS UPPERMOST POSITION, LOCATE THE FRONT SURFACE OF THE SENSOR HEAD EXACTLY FLUSH WITH THE INBOARD SURFACE OF THE MOUNTING PLATE. LOCK FIRMLY IN PLACE WITH MOUNTING BRACKET.

U. PROVIDE STRAIN-RELIEF FOR SENSOR HEAD CABLE USING CABLE CLAMP AS SHOWN ON FIGURE 3. SECURE CLAMP TO CHASSIS USING ONE OF THE SCREWS OF STEP A. USE A SLIGHTLY LONGER SCREW IF NECESSARY.

V. MAKE ALL ELECTRICAL INTERFACE CONNECTIONS (EXCEPT HIGH VOLTAGE) BETWEEN TEST FIXTURE, CONTROL CONSOLE AND ETS 406C AS INDICATED IN DRAWING NUMBER 81337- 4-5-119. APPLY POWER TO 406C AND PLACE THE CONSOLE POWER SWITCH IN THE "ON" POSITION. WITH TEST FIXTURE UPRIGHT ON A HORIZONTAL SURFACE AND MOTOR PLATFORM POSITIONED AGAINST THE PLATFORM STOP, MOMENTARILY PRESS THE "RUN" SWITCH. THE SOLENOID SHOULD PULL THE PLATFORM RAPIDLY TO THE PRESET RUBBING POSITION. THE PLATFORM SHOULD BE STRONGLY HELD IN POSITION BY THE SOLENOID FOR TEN SECONDS AFTER WHICH THE PLATFORM CAN BE MANUALLY RETURNED TO ITS ORIGINAL POSITION.

W. INSTALL MOTOR RETURN SPRING (ITEM 15) BETWEEN PLATFORM AND PLATFORM STOP AS SHOWN IN FIGURE 1. USE TWO (2) 6-32 NC X .75 SCREWS. SELECT A SPRING AND ONE OF THE FOUR THREADED HOLES IN THE PLATFORM TO PROVIDE PROPER AUTOMATIC MOVEMENT OF THE PLATFORM. SPRING MUST ALLOW SOLENOID TO MOVE PLATFORM TO THE RUBBING POSITION WHEN "RUN" SWITCH IS PRESSED, BUT SHALL HAVE ENOUGH TENSION TO CAUSE RETURN TO PLATFORM STOP AFTER THE 10 SECOND INTERVAL OR WHEN THE "ABORT" SWITCH IS PRESSED FOR EARLY TERMINATION OF RUBBING TIME.

X. VERIFY PROPER MOTOR OPERATION BY PLACING THE CONTROL CONSOLE MOTOR SWITCH IN THE "ON" POSITION. RUBBING WHEEL SHOULD ROTATE AT 100 RPM WITH 60 HZ LINE VOLTAGE APPLIED TO THE SYSTEM.

Y. VERIFY PROPER OPERATION OF SENSOR HEAD. WITH CALIBRATION PLATE (ITEM 18) MOUNTED IN SPECIMEN SLIDES SUCH THAT ITS MILLED-OUT SURFACE FACES THE SENSOR, CONNECT PLATE TO HV OUTPUT OF 406C. AFTER NORMAL "0" ADJUSTMENT AND WITH 5000 VDC APPLIED TO THE CALIBRATION PLATE, VERIFY THAT A 406C "SAMPLE CHARGE" READING OF 1000 VDC IS WITHIN THE ADJUSTMENT RANGE OF THE 406C "FULL SCALE" CONTROL. NOTE THAT A 1000 VDC "SAMPLE CHARGE" INDICATION IS ACCOMPANIED BY THE PRESENCE OF 2.00 VDC AT THE REAR-PANEL RECORDER OUTPUT.

Z. INSTALL CHASSIS COVER PLATE (DWG. NO. 81337- 4-5-102) ON BOTTOM OF CHASSIS USING SIX (6) 6-32 NC X .50 MACHINE SCREWS. INSTALL SPECIMEN HOLDER STOP (ITEM 20) IN POSITION SHOWN IN FIGURE 2. USE 10-32 NF X .75 FLAT-HEAD SCREW.

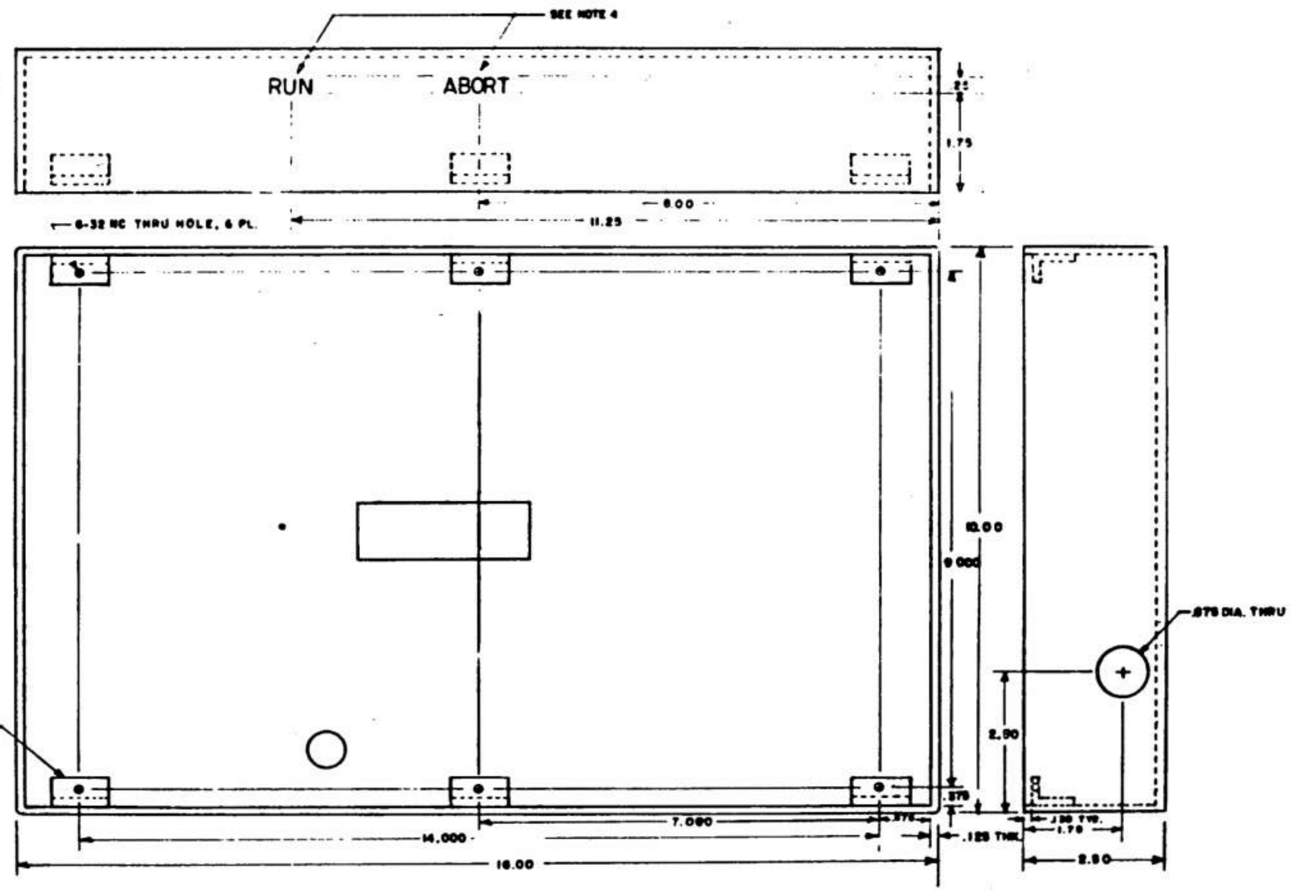
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES : FRACTIONS : 2 PLACE DIM : 3 PLACE DIM :	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46250 DATE 7/15/87 DRAWN BY Rupp CHECKED PROJ OFCR APPROVED APPROVAL DESIGN ACTIVITY	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760	TEST FIXTURE ASSEMBLY, TRIBOELECTRIC
NEXT ASSY 4-5-119 USED ON APPLICATION	APPLICABLE SPEC	SIZE D CAGE NO 81337	DRAWING NO X4-5-100
INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD-STD-100		SCALE NONE UNIT WT	SHEET 4 OF 4

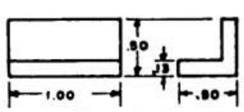
D X4-5-100

A-5

NOTES

1. UNDIMENSIONED DETAILS FOR REFERENCE ONLY; SEE SHEET 2 FOR EXACT LOCATIONS.
2. MAKE CHASSIS FROM ALUMINUM PER QQ-A-250/11, T6. WELD CORNERS OUTSIDE AND ROUND OFF.
3. MAKE SIX (6) FROM ALUMINUM PER QQ-A-200/8, 6061-T6. WELD IN PLACE BEFORE DRILLING AND TAPPING.
4. STEEL STAMP IN .25 HIGH CHARACTERS. FILL WITH BLACK EPOXY PAINT.
5. MOUNT CHASSIS COVER PLATE FROM DWG. NO. 81337-4-5-102 ON ITEM 1 BRACKETS DURING FINAL ASSEMBLY STAGE OF TEST FIXTURE. USE 6-32 NC X .30 LNG RND HD MACHINE SCREWS.





DETAIL ITEM 1
SCALE: 2/1

FIGURE 1: BASIC CHASSIS DIMENSIONS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ±; FRACTIONS ±; 2 PLACE DEC ±.05; 3 PLACE DEC ±.005	I.T.E. ASSOCIATES, INC.	US ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NEXT ASSY: 4-5-100 / USED ON / APPLICATION	DRAWN BY / CHECKED / PROJ OFCR / APPROVED / APPROVAL DESIGN ACTIVITY / APPLICABLE SPEC	CHASSIS ASSEMBLY, TEST FIXTURE
INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100		SIZE D / CAGE NO 81337 / DRAWING NO X4-5-101 / SCALE 1/1 / SHEET 1 OF 2

D X4-5-101

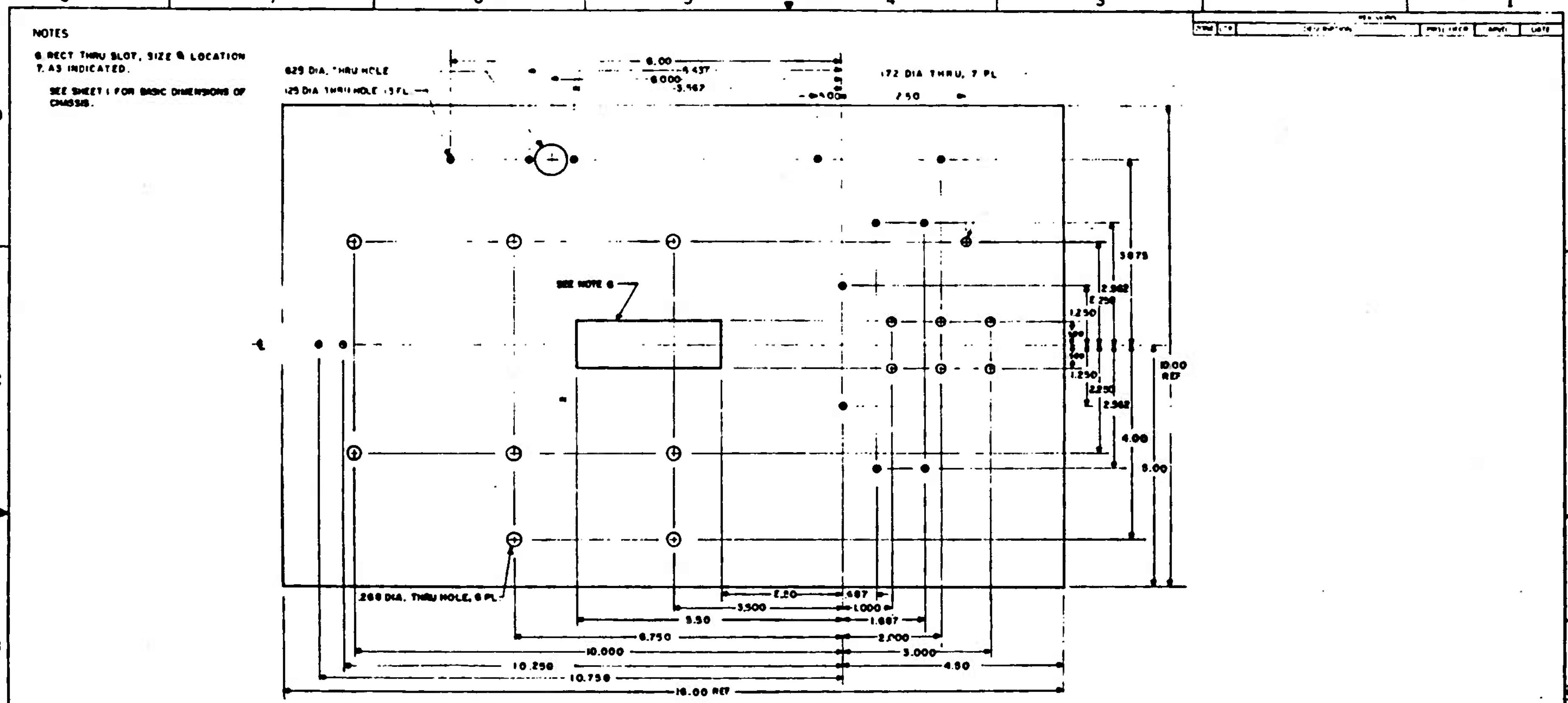


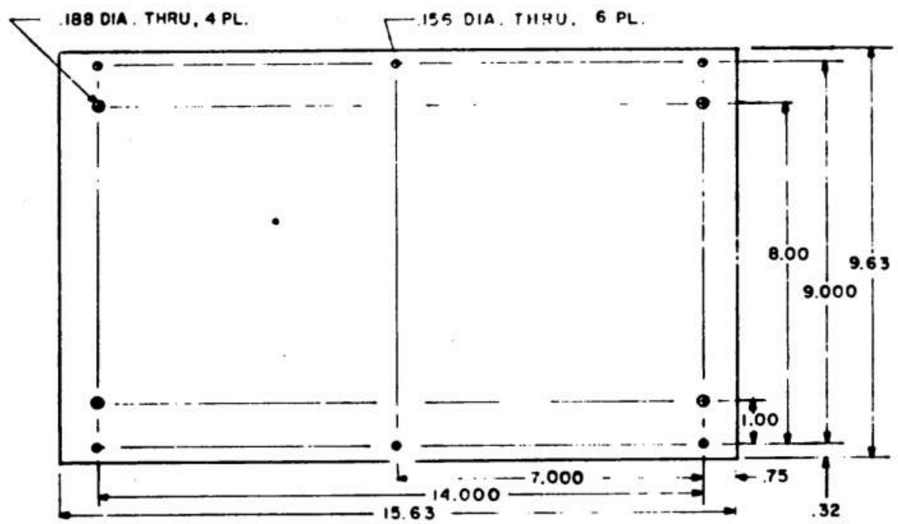
FIGURE 2: CHASSIS TOP SURFACE HOLE LOCATIONS

CHASSIS ASSEMBLY, TEST FIXTURE

D 81337 X4-5-101

NOTES:

1. MAKE FROM .125 THK ALUMINUM PER QQ-A-250/11, T651.
2. MOUNT 4 RUBBER FEET (H.H. SMITH PN2467) ON ONE SURFACE OF PLATE AT .188 DIA. HOLES. USE 8-32 NC X .50 LNG. MACHINE SCREWS AND NUTS.



REVISIONS					
ZONE	LTR	DESCRIPTION	PROJ OFCR	APVD	DATE

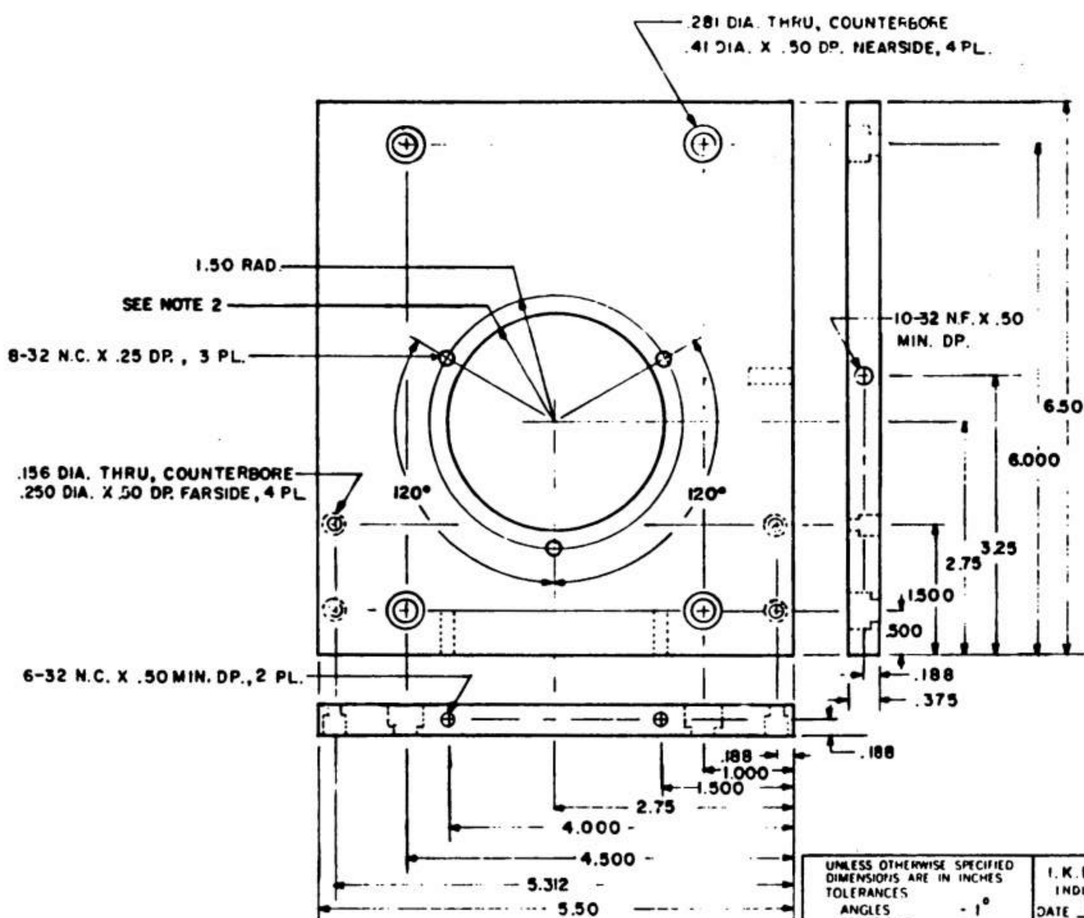
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± FRACTIONS ± 2 PLACE DIM ± .08 3 PLACE DIM ± .005	I.K.E. ASSOCIATES, INC. INDIANAPOLIS IN 462?? DATE 7/15/87	US ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760
	DRAWN BY	COVER PLATE ASSY, CHASSIS
	CHECKED	
	PROJ OFCR	
	APPROVED	
4-5-101 (NEXT ASSY) / 4-5-100 (USED ON) — APPLICATION	APPROVAL DESIGN ACTIVITY	SIZE C — CAGE NO 81337 — DRAWING NO X4-5-102
INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100	APPLICABLE SPEC	SCALE 1/2 — UNIT WT — SHEET 1 OF 1

C X4-5-102

A-8

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
2. APPROXIMATELY 1.28 RAD. THRU. OBTAIN EXACT SLIP-FIT DIMENSION FROM SHELL O.D. OF SENSOR HEAD SPECIFIED IN DWG. NO. 81337 – 4-5-117.
3. REMOVE ALL BURRS AND SHARP EDGES.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± 1° FRACTIONS ± 2 PLACE DIM ± .05 3 PLACE DIM ± .005	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46239 DATE 7/15/87
	DRAWN BY
	CHECKED
	PROJ OFCR
	APPROVED
	APPROVAL DESIGN ACTIVITY
4-5-101 NEXT ASSY / 4-5-100 USED ON — APPLICATION	APPLICABLE SPEC

US ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

MOUNTING PLATE, SENSOR HEAD

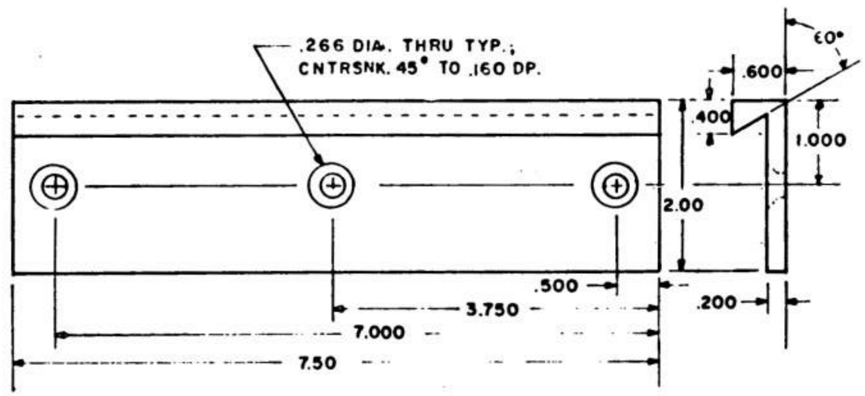
SIZE	CAGE NO	DRAWING NO
C	81337	X 4-5-103
SCALE 1/1	UNIT WT	SHEET 1 OF 1

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

C X4-5-103

NOTES:

1. MAKE FROM PTFE PER MIL P 22241, TYPE I, GRADE C.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	
TOLERANCES	
ANGLES	± 1°
FRACTIONS	±
2 PLACE DIM	± .05
3 PLACE DIM	± .005
NEXT ASSY	USED ON
4-5-101	4-5-100
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239

DATE	7/15/87
DRAWN BY	RWPE
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

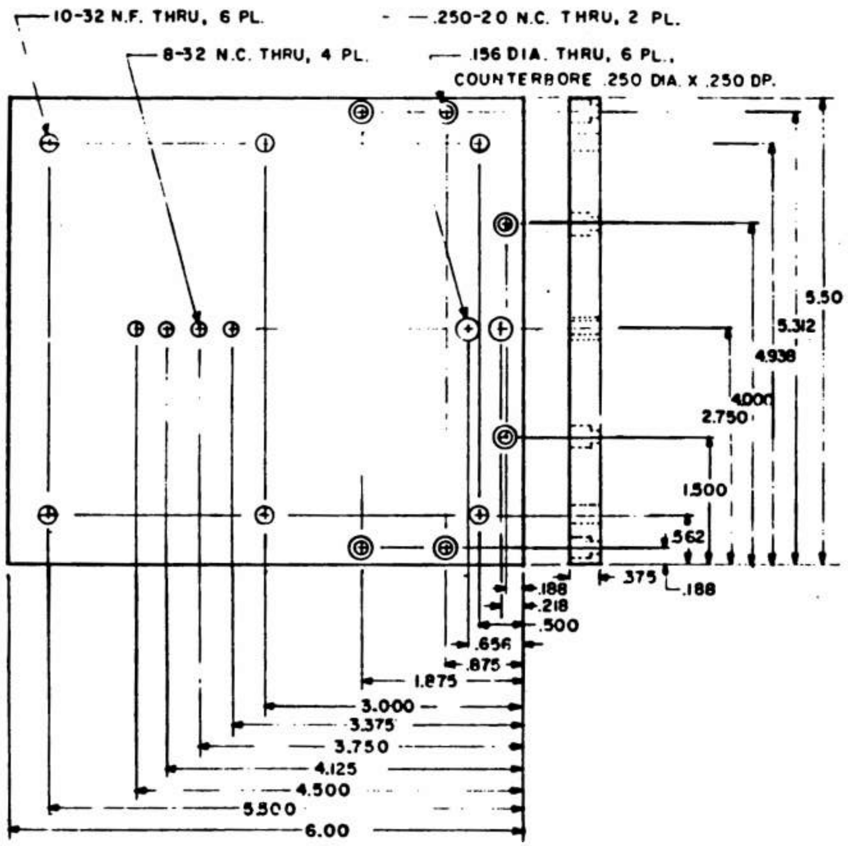
SLIDE, CHASSIS

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-104
SCALE 1/1	UNIT WT	SHEET 1 OF 1

C X4-5-104

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
2. REMOVE ALL BURRS AND SHARP EDGES.



REVISIONS		
ZONE	LTR	DESCRIPTION	PROJ OFCR	APVD	DATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
FRACTIONS ±
2 PLACE DIM ± .03
3 PLACE DIM ± .005

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239
DATE 7/15/87
DRAWN BY
CHECKED
PROJ OFCR
APPROVED
APPROVAL DESIGN ACTIVITY
APPLICABLE SPEC

NEXT ASSY	USED ON
	4-5-100
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

US ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK, MA 01760

PLATFORM, MOTOR

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-105

SCALE 1/1 UNIT WT SHEET 1 OF 1

C X4-5-105

NOTES

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
2. REMOVE ALL BURRS AND SHARP EDGES.
3. ASSEMBLE FRAME BY MATING BEAD TO GROOVE; FASTEN "FINGER-TIGHT" USING FOUR (4) 6-32 N.C. X .50 LNG. SOCKET HD. CAP SCREWS.

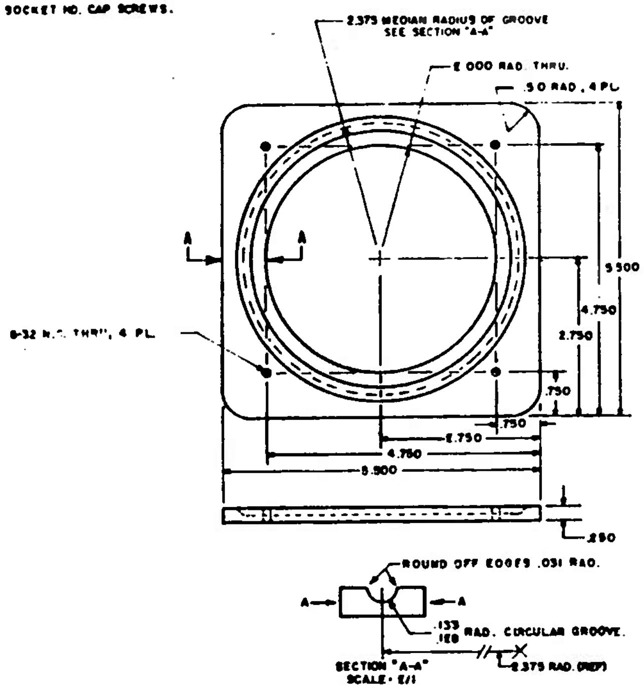


FIGURE 1: BACK PLATE

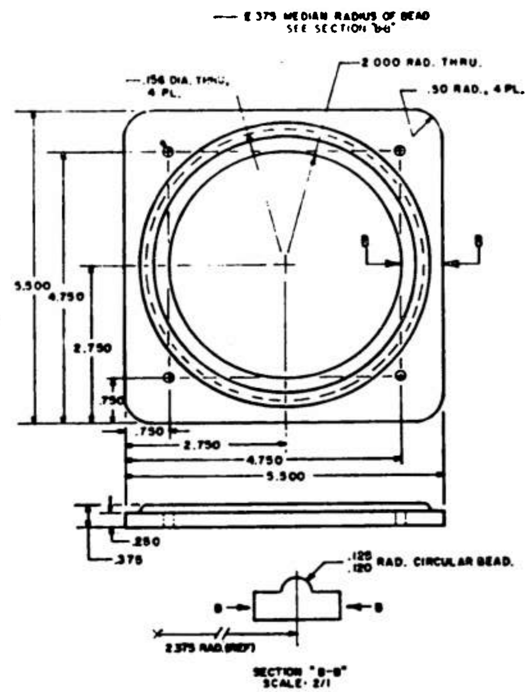


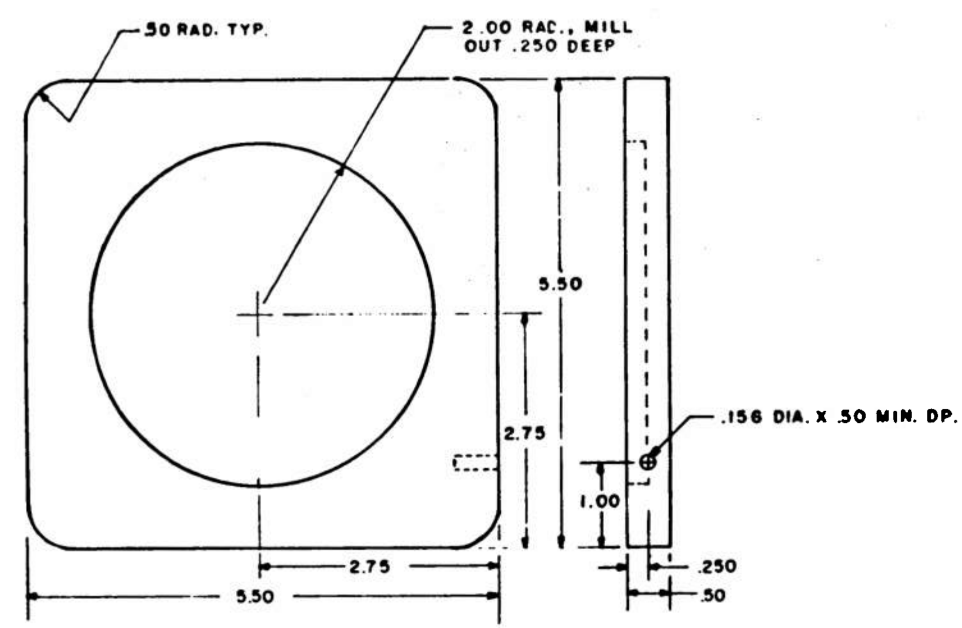
FIGURE 2: PRESSURE PLATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES : FRACTIONS : 2 PLACE DIM ±.02 3 PLACE DIM ±.005	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46239 DATE 3/10/87	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK, MA 01760	
4-5-100	DRAWN BY RAAB	SPECIMEN FRAME ASSEMBLY	
NEXT ASSY / USED ON	CHECKED		
APPLICATION	PROJ OFCR		
	APPROVED		
	APPROVAL DESIGN ACTIVITY	SIZE D / CAGE NO 81337	DRAWING NO X4-5-106
INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100	APPLICABLE SPEC	SCALE 1/1 / UNIT WT	SHEET 1 OF 1

D X4-5-106

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651. REMOVE ALL BURRS AND SHARP EDGES.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES	
ANGLES	±
FRACTIONS	±
2 PLACE DIM	±.05
3 PLACE DIM	±.005

NEXT ASSY	USED ON
	4-5-100
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46253

DATE	7/15/87
DRAWN BY	Rupe
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

US ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

PLATE, CALIBRATION

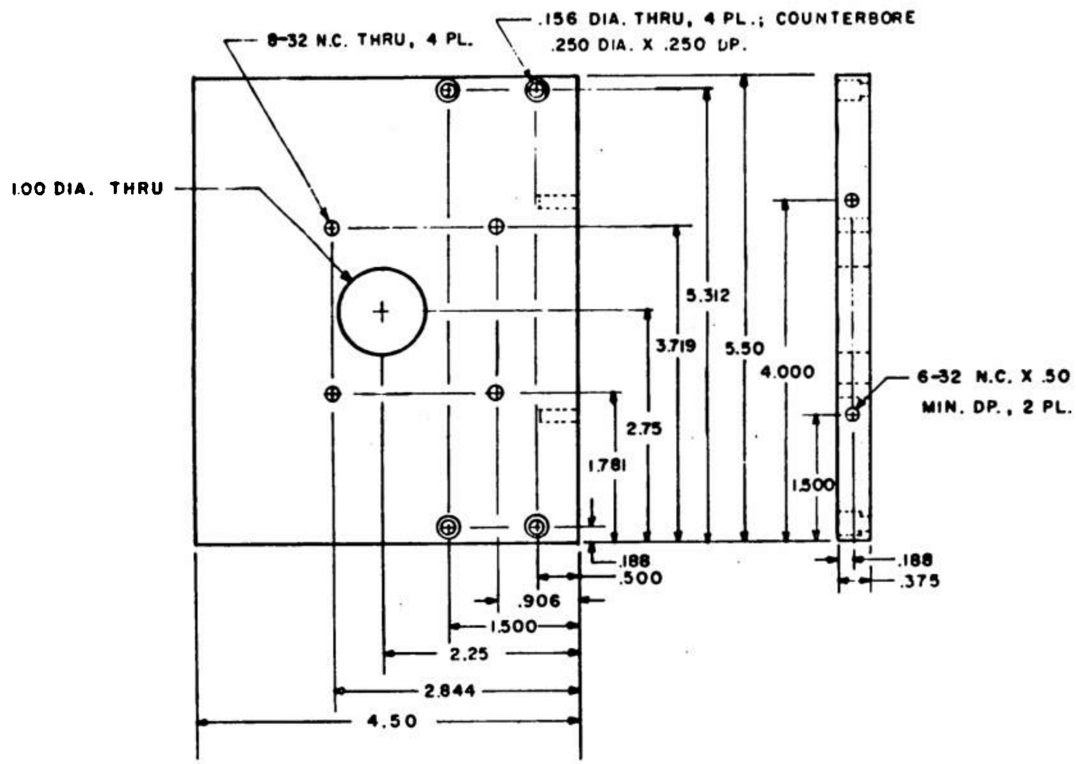
SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-107
SCALE 1/1	UNIT WT	SHEET 1 OF 1

C X4-5-107

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.

2. REMOVE ALL BURRS AND SHARP EDGES.



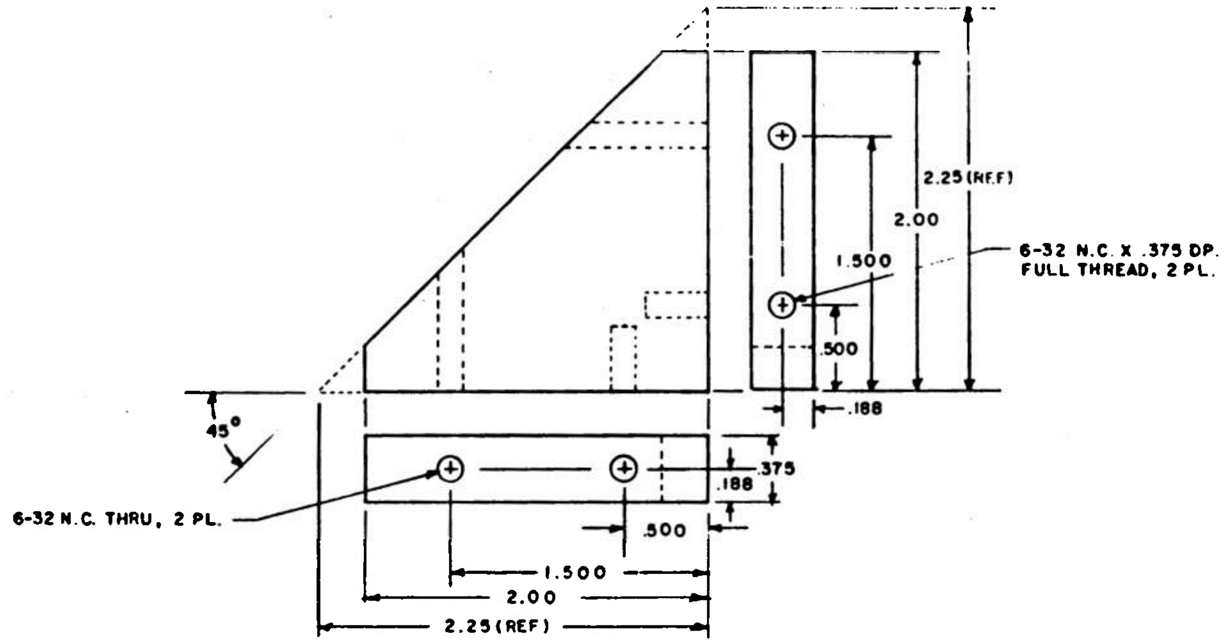
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± FRACTIONS ± 2 PLACE DIM ± .05 3 PLACE DIM ± .005	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46239 DATE 7/15/87 DRAWN BY Burs CHECKED PROJ OFCR APPROVED APPROVAL DESIGN ACTIVITY APPLICABLE SPEC	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760	
4-5-105 / NEXT ASSY	4-5-100 / USED ON	MOUNTING PLATE, MOTOR	
APPLICATION		SIZE C / CAGE NO 81337	DRAWING NO X4-5-108
		SCALE 1/1 / UNIT WT	SHEET 1 OF 1

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

C X4-5-108

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
2. REMOVE ALL BURRS AND SHARP EDGES.



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES.	
ANGLES	± 1°
FRACTIONS	±
2 PLACE DIM	± .03
3 PLACE DIM	± .005
4-5-101	
4-5-105	
4-5-103	
4-5-108	4-5-100
NEXT ASSY	USED ON
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239

DATE 7/15/87

DRAWN BY	Rupe
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

US ARMY NATICK RESEARCH & DEVELOPMENT CENTER

BRACE, REINFORCING

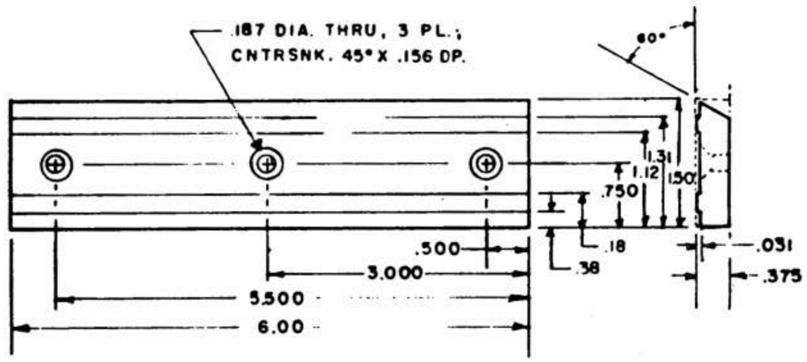
SIZE	CAGE NO	DRAWING NO
C	81337	X 4-5-109

SCALE 2/1 UNIT WT SHEET 1 OF 1

C X4-5-109

NOTES:

1. MAKE FROM PTFE PER MIL-P-22241, TYPE I, GRADE C IN THE FOLLOWING SEQUENCE:
   (a) CUT MATERIAL 6.00 X 1.50 X .375.
   (b) MAKE 60° BEVEL CUT, ONE EDGE.
   (c) MILL OUT MATERIAL LEAVING LANDS AS SHOWN.
   (d) DRILL AND COUNTERSINK HOLES.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± 1° FRACTIONS ± 2 PLACE DIM ± .05 3 PLACE DIM ± .005	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46229 DATE 7/15/87	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760	
	DRAWN BY Rupe	SLIDE, MOTOR PLATFORM	
	CHECKED		
	PROJ OFCR		
	APPROVED		
4-5-105 | 4-5-100	APPROVAL DESIGN ACTIVITY	SIZE C	CAGE NO 81337 | DRAWING NO X4-5-110
NEXT ASSY | USED ON	APPLICABLE SPEC	SCALE 1/1	UNIT WT | SHEET 1 OF 1
APPLICATION			

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

C X4-5-110

NOTES

1. MAKE FROM ALUMINUM ROUND STOCK PER QQ-A-200/8.
2. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
3. REMOVE ALL BURRS AND SHARP EDGES.

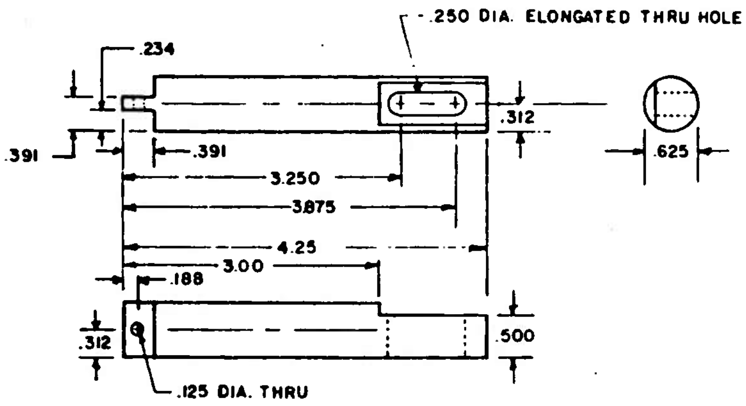


FIGURE 1: CONNECTING ROD (NOTE 1)

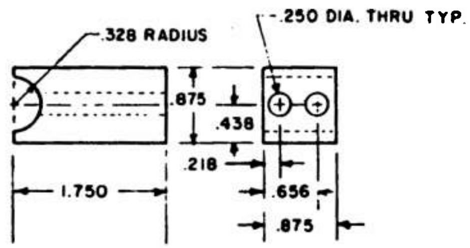


FIGURE 2: PULL BLOCK (NOTE 2)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	
TOLERANCES	
ANGLES	-
FRACTIONS	-
2 PLACE DIM	± .05
3 PLACE DIM	± .008

NEXT ASSY	USED ON
4-5-105	4-5-100
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239

DATE	7/15/87
DRAWN BY	Rapa
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK, MA 01760

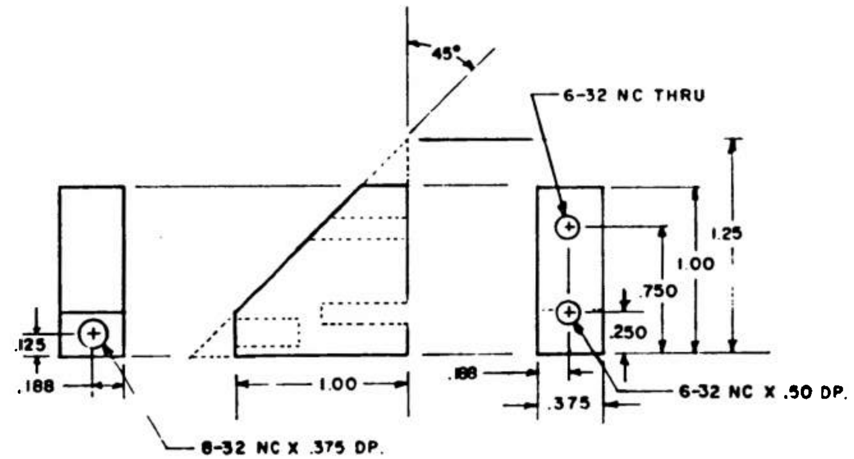
LINKAGE ASSEMBLY, SOLENOID

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-111
SCALE 1/1	UNIT WT	SHEET 1 OF 1

C X4-5-111

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651.
2. REMOVE ALL BURRS AND SHARP EDGES.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES	
ANGLES	± 1°
FRACTIONS	±
2 PLACE DIM	± .08
3 PLACE DIM	± .005

4-5-101	4-5-100
NEXT ASSY	USED ON
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I. K. E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239

DATE 7/15/87

DRAWN BY	Rupp
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

STOP, MOTOR RETURN

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-112
SCALE 2/1	UNIT WT	SHEET 1 OF 1

C X4-5-112

NOTES

1. MAKE INSULATING SECTION FROM PTFE. INSTALL .250-20 NC HELICOIL THREAD INSERTS IN .265 DIA HOLES. MAINTAIN CLEANLINESS OF TOOLS AND WORK AREA TO AVOID CONTAMINATION OF PTFE WITH METAL CHIPS OR OIL.

2. MAKE TENSION BAR IN SEQUENCE AS FOLLOWS:

(a) FORM METAL SECTION FIRST, DRILLING AND TAPPING HOLES. REMOVE ALL BURRS AND SHARP EDGES.

(b) BOND PTFE STRIP TO METAL SECTION ON SIDE OPPOSITE TAPPED HOLES. UTILIZE APPROPRIATE ADHESIVE IN ACCORDANCE WITH VENDOR INSTRUCTIONS.

(c) AFTER ADHESIVE SET-UP TIME, BEVEL ENDS OF PTFE AS SHOWN.

3. ASSEMBLE TENSION BAR TO INSULATING SECTION AS SHOWN, USING INDICATED HARDWARE. ADJUST SCREWS FOR APPROX. .48 SPACING BETWEEN PTFE FACES.

4. PTFE PER MIL-P-22241, TYPE I, GRADE A.

5. ALUMINUM PER QQ-A-200/8, 6063-T5.

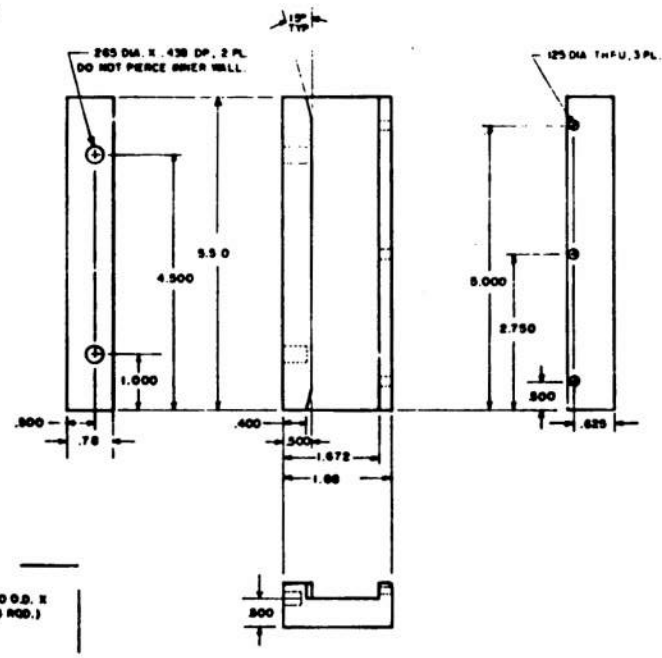


FIGURE 1: INSULATING SECTION (SEE NOTES 1 & 4)

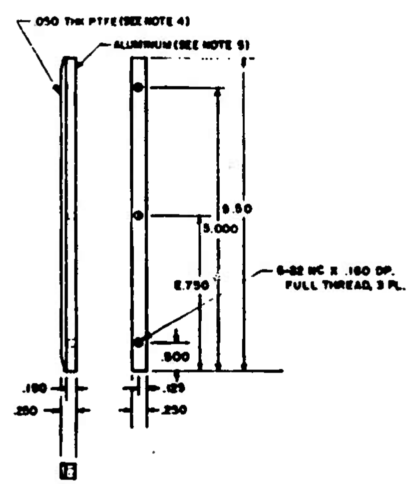


FIGURE 2: TENSION BAR (SEE NOTE 2)

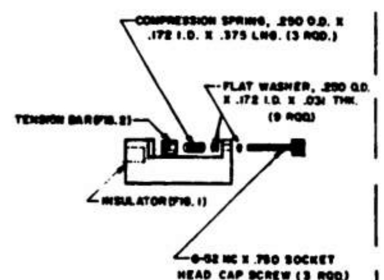


FIGURE 3: ASSEMBLY (SEE NOTE 3)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± 1° FRACTIONS ± 2 PLACE DIM ± .01 3 PLACE DIM ± .005	L.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46219
NEXT ASSY 4-8-103 USED ON 4-8-100 APPLICATION	DATE 7/18/87 DRAWN BY CHECKED PROJ OFCR APPROVED APPROVAL DESIGN ACTIVITY APPLICABLE SPEC

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK, MA 01760

SLIDE ASSEMBLY, SPECIMEN FRAME

SIZE D CAGE NO 81337 DRAWING NO X4-5-113

SCALE 1/1 SHEET 1 OF 1

D X4-5-113

NOTES

1. MAKE WHEEL AND HUB FROM STAINLESS STEEL PER QQ-S-763, TYPE 304. HUB MAY BE MADE SEPARATELY FROM STAINLESS STEEL PER QQ-S-763, TYPE 304 TO SLIP-FIT INTO A MATING THRU HOLE AT CENTER OF WHEEL, WITH WELD TACKS AROUND HUB AT POINT "A". REMOVE ALL BURRS AND SHARP EDGES.
2. MAKE 3.25 DIA DISK FROM .75 NOM THK PTFE PER MIL P 22241, TYPE I, GRADE A. THEN DRILL FOUR (4) HOLES AS SPECIFIED. INSTALL FOUR (4) .250-20 NC HELICOIL THREAD INSERTS IN HOLES. MOUNT DISK ON COMPLETED WHEEL FROM FIG. 1 USING FOUR .250-20 NC X .500 LG. SOCKET-HEAD CAP-SCREWS. MOUNT ASSEMBLY IN LATHE USING HUB C'BORE TO CENTER. TURN DISK PERIMETER TO 3.000 DIA., THEN TURN FACE TO SPECIFIED CONVEX SURFACE LEAVING .500 AVG. DISK THICKNESS AT RIM. USE CLEAN TOOLS AND WORK AREA TO AVOID CONTAMINATING PTFE WITH METAL CHIPS OR OILS.

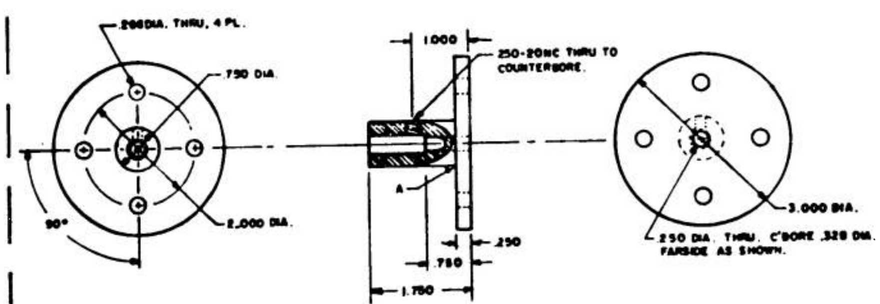


FIGURE 1: WHEEL AND HUB (SEE NOTE 1)

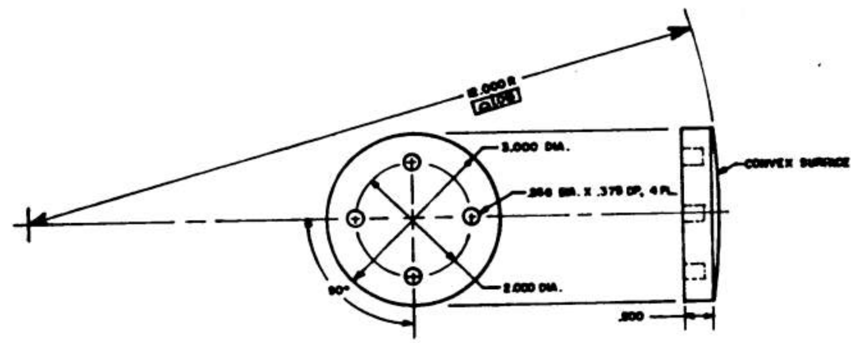


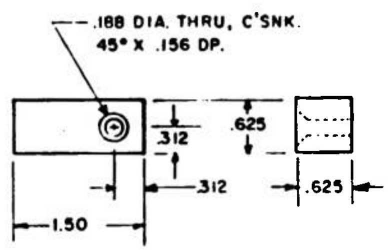
FIGURE 2 RUBBING DISK (SEE NOTE 2)

I.R.E. ASSOCIATES, INC.	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
RUBBING WHEEL ASSEMBLY	
SIZE D	CAGE NO 81337
DWG NO	X4-5-114
SCALE	1/1
SHEET	1 OF 1

D X4-5-114

NOTES.

1. KEEP TOOLS AND WORK AREA CLEAN TO AVOID CONTAMINATING PTFE WITH OILS AND METAL CHIPS.
2. MAKE FROM PTFE PER MIL-P-22241, TYPE I, GRADE A.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES : FRACTIONS : 2 PLACE DIM : .01 3 PLACE DIM : .005	
4-5-103	4-5-100
NEXT ASSY	USED ON
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E ASSOCIATES, INC. INDIANAPOLIS, IN 46239	
DATE 7/15/87	
DRAWN BY	Rupe
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

US ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

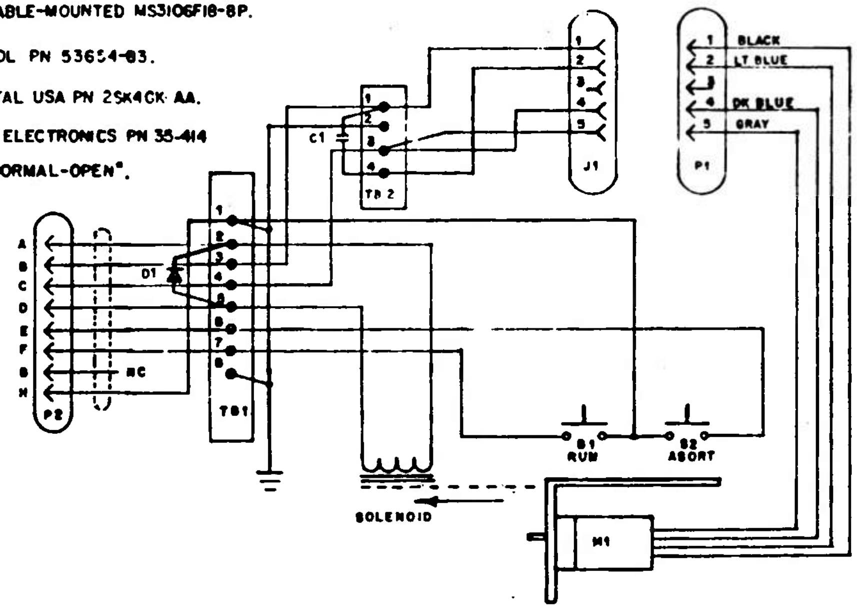
STOP, SPECIMEN HOLDER

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-115
SCALE 1/1	UNIT WT	SHEET 1 OF 1

C X4-5-115

NOTES:

1. SEE DWG NO 81337- 4-5-117 FOR SENSOR HEAD.
2. CAPACITOR C1 IS 1μFd., 400 WV MYLAR.
3. DIODE D1 IS 1N4001. OBSERVE CORRECT POLARITY.
4. CONNECTOR J1 IS PANEL-MOUNTED 5-PIN DIN RECEPTACLE.
5. CONNECTOR P1 IS CABLE-MOUNTED 5-PIN DIN PLUG.
6. CONNECTOR P2 IS CABLE-MOUNTED MS3106F18-8P.
7. SOLENOID IS DELTROL PN 53654-83.
8. MOTOR M1 IS ORIENTAL USA PN 2SK4CK-AA.
9. SWITCHES ARE GC ELECTRONICS PN 35-414 OR EQUAL, WIRED "NORMAL-OPEN".



REVISIONS					
ZONE	LTR	DESCRIPTION	PROJ OFCR	APVD	DATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± FRACTIONS ± 2 PLACE DIM ± 3 PLACE DIM ±		I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46239 DATE 7/15/87	U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK MA 01760	
		DRAWN BY Ruge	WIRING DIAGRAM, TRIBO-ELECTRIC TEST FIXTURE	
		CHECKED		
		PROJ OFCR		
		APPROVED		
4-5-101		APPROVAL DESIGN ACTIVITY	SIZE C CAGE NO 81337	DRAWING NO X4-5-116
4-5-100	4-5-100			
NEXT ASSY	USED ON	APPLICABLE SPEC		
APPLICATION			SCALE NONE UNIT WT	SHEET 1 OF 1

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

C X4-5-116

ZONE	LTR	DESCRIPTION	DATE	APPD

NOTES:

1. LISTED PART NUMBER DESCRIBES AN ASSEMBLY DESIGNED AS A PART OF ELECTRO-TECH SYSTEMS MODEL 406C STATIC DECAY METER. THE ASSEMBLY USED FOR THE APPLICATION STATED HEREIN SHALL MEET ALL REQUIREMENTS OF THE PART NUMBER WITH THE FOLLOWING EXCEPTIONS:

(a) THE APERTURE IN THE SENSOR SHELL SHALL HAVE DIAMETER AND LOCATION TO PROVIDE, WHEN PROPERLY CONNECTED TO AND OPERATING WITH AN ETS MODEL 406C, A FRONT PANEL "SAMPLE CHARGE" INDICATION OF 1 KV WHILE THE SENSOR APERTURE IS AIMED AT THE CENTER OF AN APPROPRIATELY SIZED FLAT METAL TARGET FROM A DISTANCE OF 0.75 INCHES. THE TARGET SHALL BE CHARGED TO 5 KVDC AND THE 406C "CALIBRATE FULL SCALE" CONTROL SHALL BE AT MID-RANGE DURING THIS MEASUREMENT. A .375 DIA. APERTURE IN THE SAME LOCATION AS THE ORIGINAL HAS BEEN FOUND APPROPRIATE IN THE PROTOTYPE OF THE APPLICATION. SINCE REDUCTION OF THE APERTURE AREA IS ACCOMPANIED BY A REDUCTION IN "FULL SCALE" CONTROL RANGE, THE ACTUAL APERTURE SIZE IN PRODUCTION ITEMS IS CRITICAL.

(b) IN THE EVENT THE ASSEMBLY IS INTENDED FOR USE IN A TEST CHAMBER HAVING FEED-THRU CONNECTORS, THE ASSEMBLY CABLE SHALL HAVE AN EXPOSED TOTAL LENGTH OF 25±2 INCHES.

SUGGESTED SOURCE(S) OF SUPPLY:

IDENTIFICATION OF THE "SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).

ELECTRO-TECH SYSTEMS, INC. (CODE IDENT NO 56541)
115 EAST GLENSIDE AVENUE
GLENSIDE, PA 19038

PART NUMBER: ETS-5033*

*SEE NOTES FOR ALTERATIONS TO SPECIFIED PART.

ALTERED ITEM DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
FRACTIONS ±
2 PLACE DIM ±
3 PLACE DIM ±

NEXT ASSY	USED ON
4-5-103	4-5-100

APPLICATION

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239
DATE 7/15/87

DRAWN BY	Rupe
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

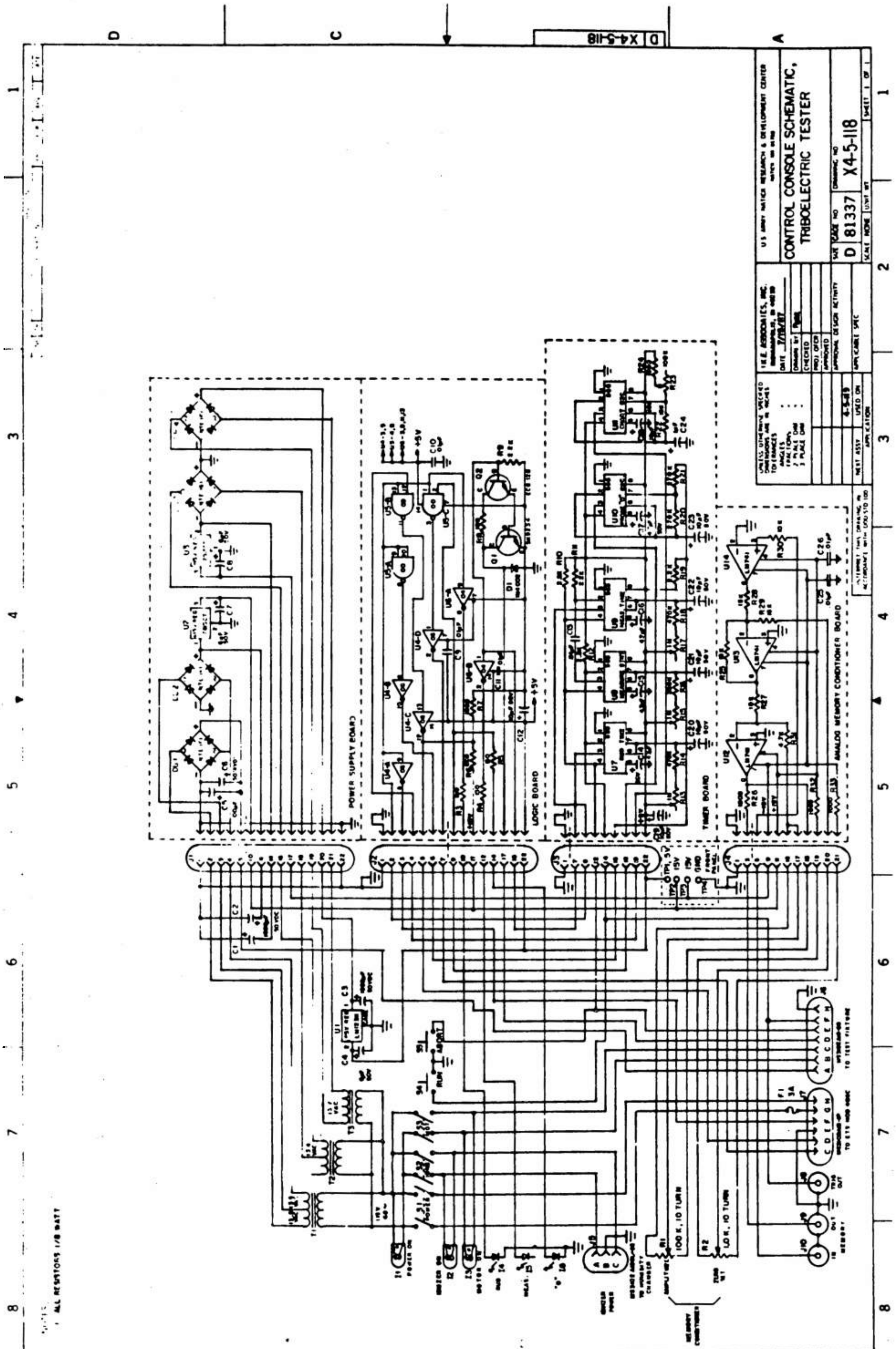
U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

SENSOR HEAD ASSEMBLY

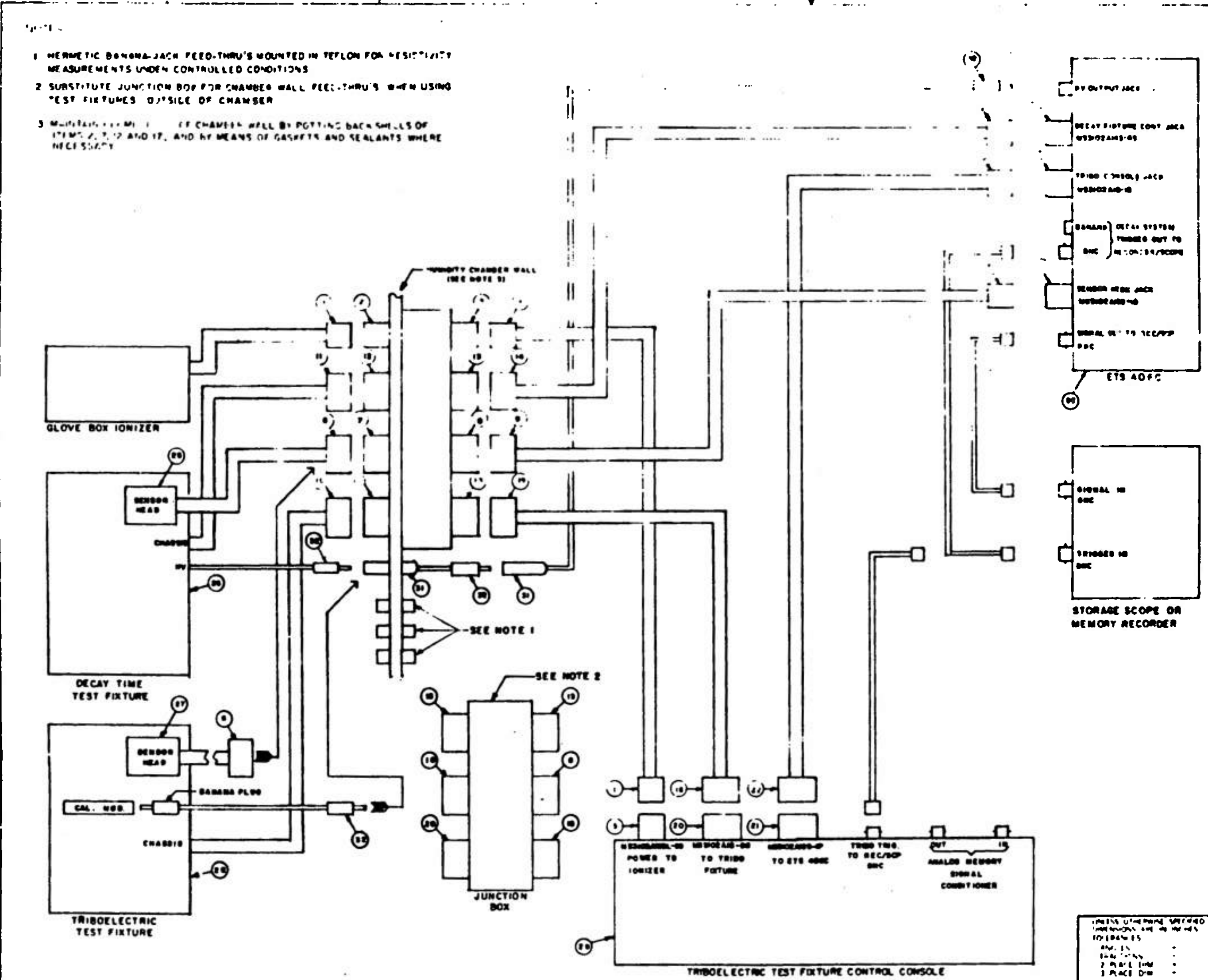
SIZE	CAGE NO	DRAWING NO
C	81337	X 4-5-117

SCALE	UNIT WT	SHEET
NONE		1 OF 1

C X4-5-117



X4-5-118
U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER
CONTROL CONSOLE SCHEMATIC, TRIBOELECTRIC TESTER
D 81337
X4-5-118
POWER SUPPLY BOARD
LOGIC BOARD
TIMER BOARD
ANALOG MEMORY CONDITIONER BOARD



ITEM OR FIND NO.	QTY. REQD.	CAGE NO.	PART NUMBER OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
32	4	01900	[illegible]	PLUG, HIGH VOLTAGE
31	2	01900	[illegible]	JACK, HIGH VOLTAGE
30	1	81337	4-5-170	STATIC DECAY METER, MODIFIED
29	1	81337	4-5-110	CONTROL CONSOLE, TRIBOELECTRIC
28	1	81337	[illegible]	TEST FIXTURE, TRIBOELECTRIC
27	1	81337	4-5-117	SENSOR HEAD, MODIFIED
26	1	81337	[illegible]	TEST FIXTURE, DECAY TIME, MOD
25	1	81337	[illegible]	SENSOR HEAD, MODIFIED
24	1		[illegible]	CONN, RCPT, BLKHD, 10 COND.
23	1		[illegible]	CONN, PLG, CBL, 10 COND.
22	1		[illegible]	CONN, RCPT, CBL, 10 COND.
21	1		[illegible]	CONN, PLG, BLKHD, 10 COND.
20	2		[illegible]	CONN, RCPT, BLKHD, 8 COND.
19	1		[illegible]	CONN, RCPT, CBL, 8 COND.
18	2		[illegible]	CONN, PLG, BLKHD, 8 COND.
17	1		[illegible]	CONN, RCPT, BLKHD, 8 COND.
16	2		[illegible]	CONN, PLG, CBL, 8 COND.
15	2		[illegible]	CONN, RCPT, BLKHD, 6 COND.
14	1		[illegible]	CONN, RCPT, CBL, 6 COND.
13	2		[illegible]	CONN, PLG, BLKHD, 6 COND.
12	1		[illegible]	CONN, RCPT, BLKHD, 6 COND.
11	2		[illegible]	CONN, PLG, CBL, 6 COND.
10	2		[illegible]	CONN, RCPT, BLKHD, 7 COND.
9	1		[illegible]	CONN, RCPT, CBL, 7 COND.
8	2		[illegible]	CONN, PLG, BLKHD, 7 COND.
7	1		[illegible]	CONN, RCPT, BLKHD, 7 COND.
6	3		[illegible]	CONN, PLG, CBL, 7 COND.
5	1		[illegible]	CONN, RCPT, BLKHD, 5 COND.
4	1		[illegible]	CONN, RCPT, CBL, 5 COND.
3	1		[illegible]	CONN, PLG, BLKHD, 5 COND.
2	1		[illegible]	CONN, RCPT, BLKHD, 5 COND.
1	2		[illegible]	CONN, PLG, CBL, 5 COND.

PARTS LIST

I K E ASSOCIATES, INC.

DATE 7/15/87

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER

ELECTRICAL INTERFACE DIAGRAM, DECAY-TIME AND TRIBOELECTRIC TEST EQUIPMENT

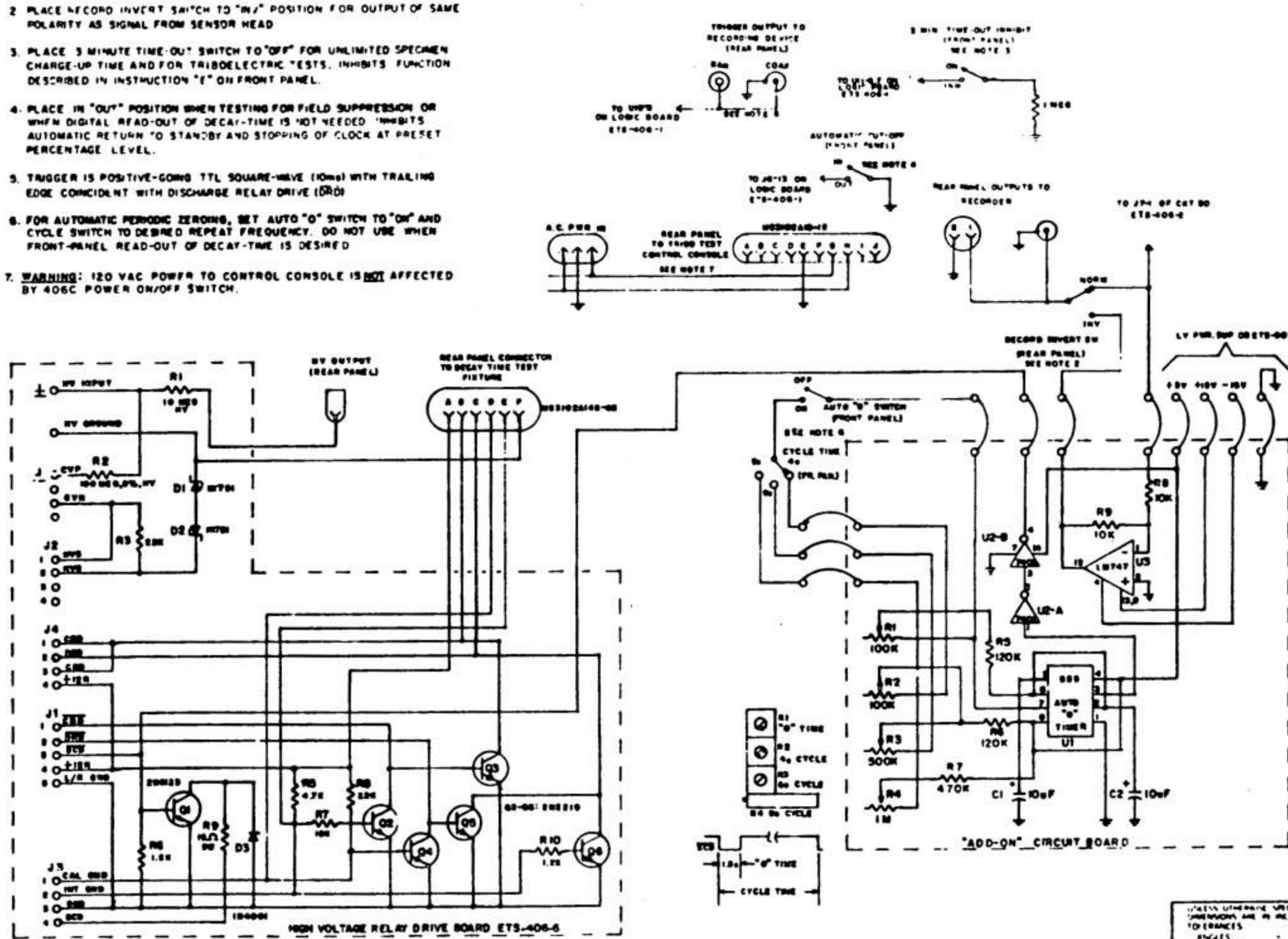
SIZE D CAGE NO 81337 DRAWING NO X4-5-119

SCALE NONE SHEET 1 OF 1

D X4-5-119

NOTES

1. TIMING RESISTOR R35 AT U29 ON LOGIC BOARD ETS-406-1 INCREASED FROM 180K TO 1MEG ALLOWING SYNCHRO-DRIVEN CHART RECORDER PEN TO REACH FULL SCALE PRIOR TO $\overline{\text{UHD}}$ EVENT. (STATIC DECAY TESTS).
2. PLACE RECORD INVERT SWITCH TO "INV" POSITION FOR OUTPUT OF SAME POLARITY AS SIGNAL FROM SENSOR HEAD.
3. PLACE 3 MINUTE TIME-OUT SWITCH TO "OFF" FOR UNLIMITED SPECIMEN CHARGE-UP TIME AND FOR TRIBOELECTRIC TESTS. INHIBITS FUNCTION DESCRIBED IN INSTRUCTION "E" ON FRONT PANEL.
4. PLACE IN "OUT" POSITION WHEN TESTING FOR FIELD SUPPRESSION OR WHEN DIGITAL READ-OUT OF DECAY-TIME IS NOT NEEDED. INHIBITS AUTOMATIC RETURN TO STANDBY AND STOPPING OF CLOCK AT PRESET PERCENTAGE LEVEL.
5. TRIGGER IS POSITIVE-GOING TTL SQUARE-WAVE (10ms) WITH TRAILING EDGE COINCIDENT WITH DISCHARGE RELAY DRIVE ($\overline{\text{DRD}}$).
6. FOR AUTOMATIC PERIODIC ZEROING, SET AUTO "O" SWITCH TO "ON" AND CYCLE SWITCH TO DESIRED REPEAT FREQUENCY. DO NOT USE WHEN FRONT-PANEL READ-OUT OF DECAY-TIME IS DESIRED.
7. **WARNING**: 120 VAC POWER TO CONTROL CONSOLE IS **NOT** AFFECTED BY 406C POWER ON/OFF SWITCH.

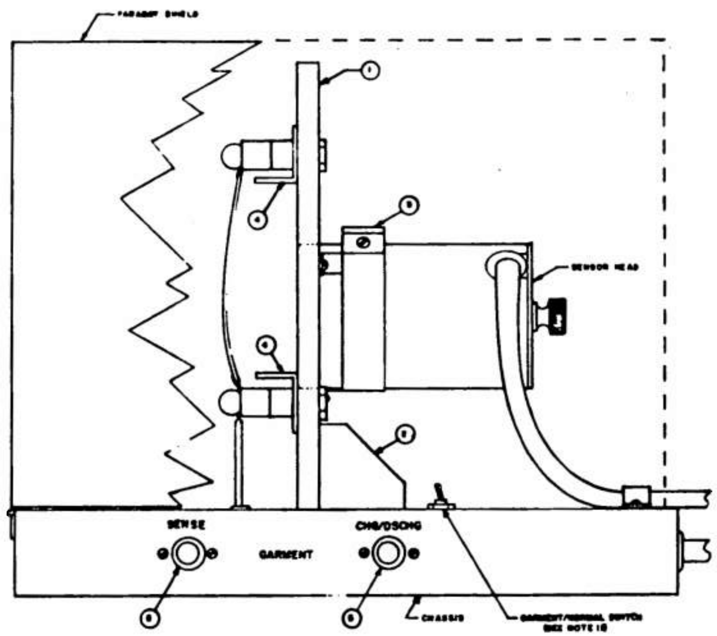


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN	U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER
	DATE 7/15/87	MODIFICATION SCHEMATIC, INSTRUMENT, ETS MODEL 406C, SN: SDM-406C-0318
4-5-119 NEXT ASSY / USED ON	APPLICABLE SPEC	SIZE D / CAGE NO 81337 / DRAWING NO X4-5-120
		SCALE NONE / SHEET 1 OF 1

D X4-5-120

NOTES

1. REMOVE SENSOR-HEAD AND CABLE FROM TEST FIXTURE. IF FIXTURE IS INTEND FOR USE IN CHAMBER HAVING FEED-THRU CONNECTOR, SHORTEN THIS CABLE TO ≈25 INCHES
2. REMOVE ALL SENSOR-HEAD MOUNTING HARDWARE FROM CHASSIS. DISCARD HDWR
3. DISCONNECT HV LEAD AND JUMPER WIRE FROM SPECIMEN ELECTRODES. REMOVE ELECTRODES FROM MOUNTING PLATE. REMOVE AND DISCARD ORIGINAL MOUNTING PLATE
4. REMOVE AND DISCARD ORIGINAL CHASSIS INTERLOCK CABLE, LEAVING THE 2 MICRO-SWITCHES IN PLACE. REMOVE AND DISCARD CHASSIS GROUND LEAD.
5. DRILL APPROPRIATE HOLES IN CHASSIS AND MOUNT 2 HV JACKS (ITEM 5) AT APPROXIMATE INDICATED LOCATIONS
7. FABRICATE ADD-ON CIRCUIT BOARD IN ACCORDANCE WITH DWG. NO. 81337-4-5-122 USING THE INDICATED COMPONENTS. PHYSICALLY LOCATE HV COMPONENTS K1, 2 AND 3 TO MINIMIZE LENGTH OF HV CIRCUITRY ON SPECIMEN SIDE OF RELAYS K1 AND K2.
8. ASSEMBLE NEW MOUNTING PLATE (ITEM 1) TO CHASSIS. REINFORCE WITH 2 BRACES (ITEM 2) AT LOWER CORNERS, DRILLING HOLES IN CHASSIS FOR SCREWS.
9. ASSEMBLE SPECIMEN ELECTRODES TO MOUNTING PLATE IN ORIGINAL POSITION USING INSULATIVE BOLTS AND STAND-OFFS REMOVED EARLIER. INSERT 2 SHIELDS (ITEM 4) BETWEEN STAND-OFFS AND PLATE AS INDICATED. SHIELDS MUST EXTEND BEYOND BOTH ENDS OF EACH ELECTRODE.
10. INSTALL ADD-ON CIRCUIT BOARD (NOTE 7) AT CONVENIENT LOCATION INSIDE CHASSIS, DRILLING HOLES AND USING HARDWARE AS NECESSARY.
11. DRILL HOLE IN TOP OF CHASSIS AT APPROXIMATE LOCATION SHOWN AND INSTALL SPST TOGGLE SWITCH. CHOOSE LOCATION TO AVOID INTERFERENCE WITH OTHER CHASSIS-MOUNTED ITEMS.
12. FABRICATE NEW CONTROL CABLE (8 CONDUCTOR) USING MS3106F14S-8P CONN. AS TERMINATION AT ONE END. ALLOW FOR 48 INCH CABLE LENGTH EXTERNAL TO CHASSIS. IF FIXTURE WILL BE USED IN CHAMBER WITH FEED-THRU CONNECTOR, ALLOW APPROXIMATELY 20 INCHES.
13. INSTALL CABLE IN PLACE OF INTERLOCK CABLE (NOTE 4), PROVIDE STRAIN-RELIEF AND 12 INCH CONDUCTOR LENGTH INSIDE CHASSIS.
14. REMOVE SUFFICIENT LENGTH FROM LUG END OF HV LEAD (NOTE 3) TO REACH FROM LOWER SPECIMEN ELECTRODE TO SPECIMEN END OF K3 ON CIRCUIT BOARD.
15. CONNECT JUMPER WIRE (NOTE 3) AND HV LEAD WITH LUG TO ELECTRODES IN ORIGINAL POSITION. SOLDER FREE END OF HV LEAD TO SPECIMEN TERMINAL OF K3 TOGETHER WITH LEAD FROM GARMENT "SENSE" JACK. SOLDER LEAD FROM GARMENT "CHG/DSCHG" JACK TO THE HV JUNCTION OF K1, K2 AND K3.
16. FEED UNTERMINATED END OF REMAINDER OF HV LEAD (NOTE 14) THRU ORIGINAL GROMMET IN CHASSIS END. PROVIDE STRAIN-RELIEF AND SOLDER HV LEAD TO FREE END OF K1 ON CIRCUIT BOARD. IF FIXTURE IS TO BE USED IN CHAMBER WITH HV FEED-THRU, SHORTEN THE EXTERNAL LENGTH OF HV LEAD TO ABOUT 20 INCHES. RETAIN ORIGINAL CONNECTOR AT OUTBOARD END.
17. MAKE ALL REMAINING ELECTRICAL CONNECTIONS BETWEEN CIRCUIT BOARD, CHASSIS-MOUNTED COMPONENTS AND CONTROL CABLE AS INDICATED ON DWG. NO. 81337-4-5-122. USE POINT-TO-POINT WIRING AS NECESSARY.
18. COVER ALL HV JUNCTION POINTS OF CIRCUIT BOARD COMPONENTS WITH SILICON SEALANT GENERAL ELECTRIC PN RE-340 OR EQUAL.
19. INSTALL MOUNTING BRACKET (ITEM 3) AT THE LOCATION INDICATED. INSERT SENSOR-HEAD (NOTE 1) THRU MOUNTING BRACKET INTO PLATE UNTIL STOPPED BY SHIELD. ROTATE SENSOR-HEAD TO PLACE ORIFICE IN UPPERMOST POSITION. LOCK FIRMLY IN PLACE WITH BRACKET. PROVIDE STRAIN-RELIEF FOR CABLE AT CHASSIS AS SHOWN.



ITEM OR FIND NO.	QTY. REQD.	CAGE NO.	PART NUMBER OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
5	2	[illegible]	[illegible]	HV JACK ASSEMBLY
4	2	81337	4-5-[illegible]	ELECTRODE SHIELD ASSY.
3	1	[illegible]	[illegible]	BRACKET, MOUNTING
2	1	81337	4-5-[illegible]	BRACE, MOUNTING PLATE
1	1	81337	4-5-[illegible]	MOUNTING PLATE, [illegible]

PARTS LIST

ALTERED ITEM DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± FRACTIONS ± 2 PLACE DIM ± 3 PLACE DIM ±	I.K.E. ASSOCIATES, INC. INDIANAPOLIS, IN 46270
NEXT ASSY / USED ON: 4-5-120, 4-5-119 — APPLICATION	DATE 7/15/87; DRAWN BY [illegible]; CHECKED; PROJ OFCR; APPROVED; APPROVAL DESIGN ACTIVITY; APPLICABLE SPEC

U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER NATICK, MA 01760

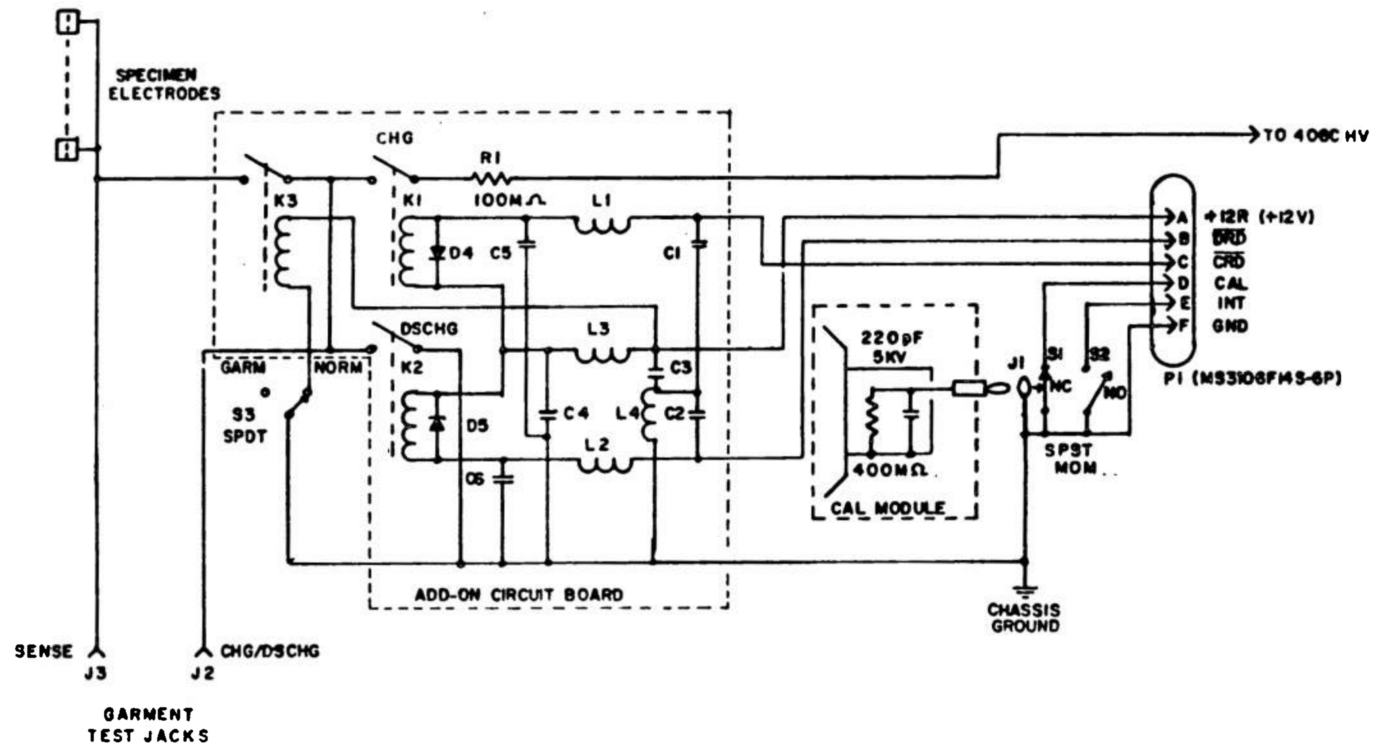
TEST FIXTURE, STATIC DECAY, PART OF ETS MODEL 406C SN: SDM-406C-0318

SIZE D | CAGE NO 81337 | DRAWING NO X4-5-121

SCALE NONE | UNIT WT | SHEET 1 OF 1

D X4-5-121

NOTES:
1. C1 THRU C6 = 0.1 uF.
2. D4, D5 = 1N4001
3. L1 THRU L4 = 39uH.
4. K1 THRU K3 = COTO, INC. PN 1387-12-01.
5. S1, S2 = MOMENTARY MICRO-SWITCHES.
6. S1 DISABLES K2 WHEN CAL MODULE PLUG IS INSERTED IN J1.
7. S2 ENABLES K1 OPERATION WHILE FARADAY CAGE IS CLOSED.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± FRACTIONS ± 2 PLACE DIM ± 3 PLACE DIM ±	
	4-5-121
NEXT ASSY	USED ON
APPLICATION	

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239
DATE 7/15/87
DRAWN BY Rupe
CHECKED
PROJ OFCR
APPROVED
APPROVAL DESIGN ACTIVITY
APPLICABLE SPEC

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

CHASSIS SCHEMATIC, DECAY-TIME TEST FIXTURE

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-122

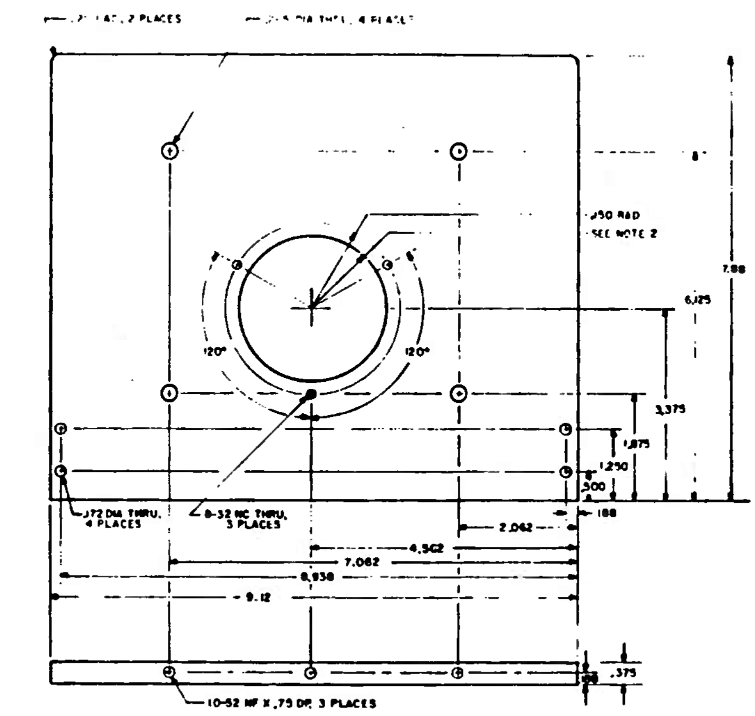
SCALE NONE | UNIT WT | SHEET 1 OF 1

C X4-5-122

NOTES

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651. REMOVE ALL BURRS AND SHARP EDGES.

2. APPROXIMATELY 1.28 RAD THRU. OBTAIN EXACT "SLIP-FIT" DIMENSION FROM SHELL O.D. OF SENSOR HEAD.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	
TOLERANCES	
ANGLES	± 1°
FRACTIONS	±
2 PLACE DIM	± .03
3 PLACE DIM	± .005

I.K.E. ASSOCIATES, INC

DATE 7/18/87

U.S. ARMY NATICK RESEARCH & DEVELOPMENT CENTER

MOUNTING PLATE, SPECIMEN

SIZE	CAGE NO	DRAWING NO
D	81337	X4-5-123

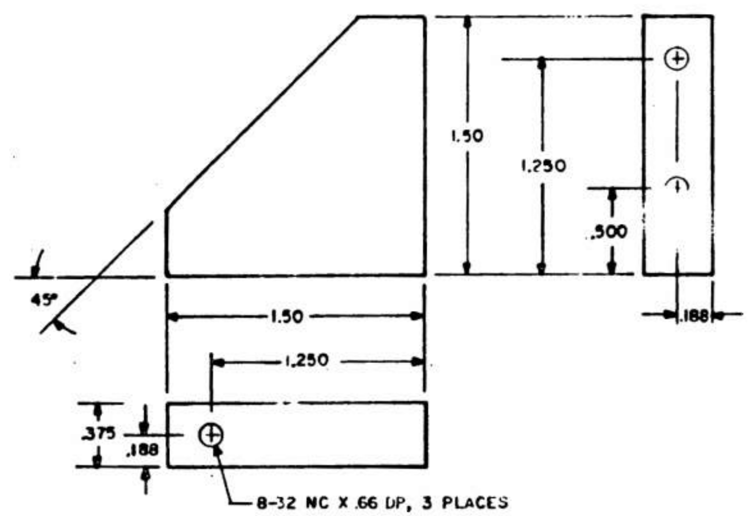
SCALE 1/1 SHEET 1 OF 1

NEXT ASSY	USED ON
4-5-121	4-6-121

D X4-5-123

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-250/11, T651. REMOVE ALL BURRS AND SHARP EDGES.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES	
ANGLES	±1°
FRACTIONS	±
2 PLACE DIM	±.05
3 PLACE DIM	±.005

NEXT ASSY	USED ON
4-5-121	

APPLICATION

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46...

DATE 7/15/87

DRAWN BY	Rupa
CHECKED	
PROJ OFCR	
APPROVED	
APPROVAL DESIGN ACTIVITY	
APPLICABLE SPEC	

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK, MA 01760

BRACE, MOUNTING PLATE

SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-124

SCALE 2/1 | UNIT WT | SHEET 1 OF 1

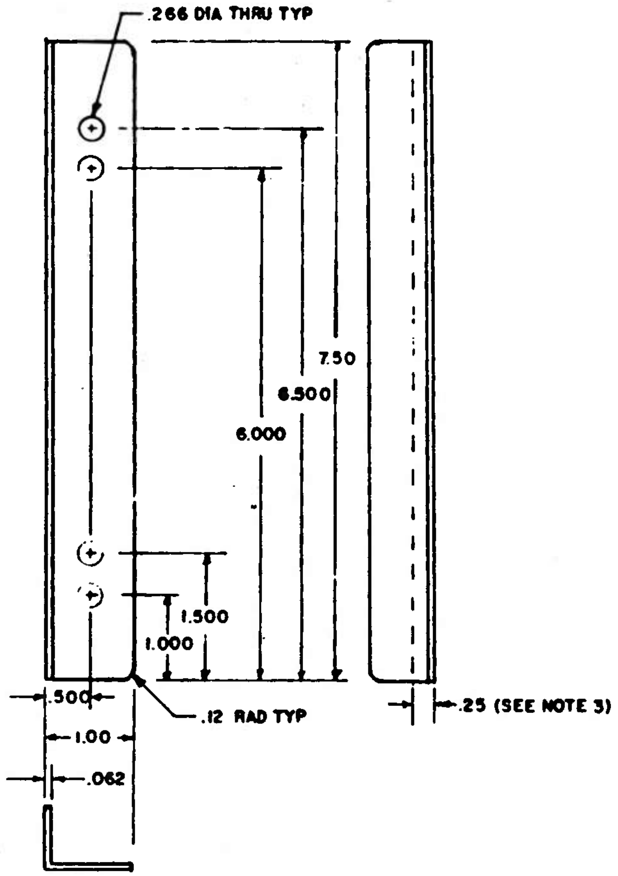
REVISIONS

ZONE	LTR	DESCRIPTION	PROJ OFCR	APVD	DATE

C X4-5-124

NOTES:

1. MAKE FROM ALUMINUM PER QQ-A-200/8, 6061-T6. REMOVE ALL BURRS AND SHARP EDGES.
2. COAT ENTIRE SHIELD WITH PLASTIC BY DIPPING IN "PLASTI DIP", PDI, INC., ST. PAUL, MN 55113. APPLY 2 COATS PER MFGR'S INSTRUCTIONS.
3. AFTER RECOMMENDED DRYING TIME, SLIT PLASTIC THRU TO METAL ON BOTH NEAR AND FAR SIDES AT LOCATION INDICATED BY DASHED LINE. REMOVE ALL COATING FROM THE SHIELD EXCEPT THE PORTION TO THE LEFT OF THE DASHED LINE.



REVISIONS					
ZONE	LTR	DESCRIPTION	PROJ OFFCR	APVD	DATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
FRACTIONS ±
2 PLACE DIM ±.03
3 PLACE DIM ±.005

NEXT ASSY	USED ON
4-5-121	

APPLICATION

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239
DATE 7/15/87
DRAWN BY Rups
CHECKED
PROJ OFCR
APPROVED
APPROVAL DESIGN ACTIVITY
APPLICABLE SPEC

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK MA 01760

SHIELD ASSEMBLY, ELECTRODE

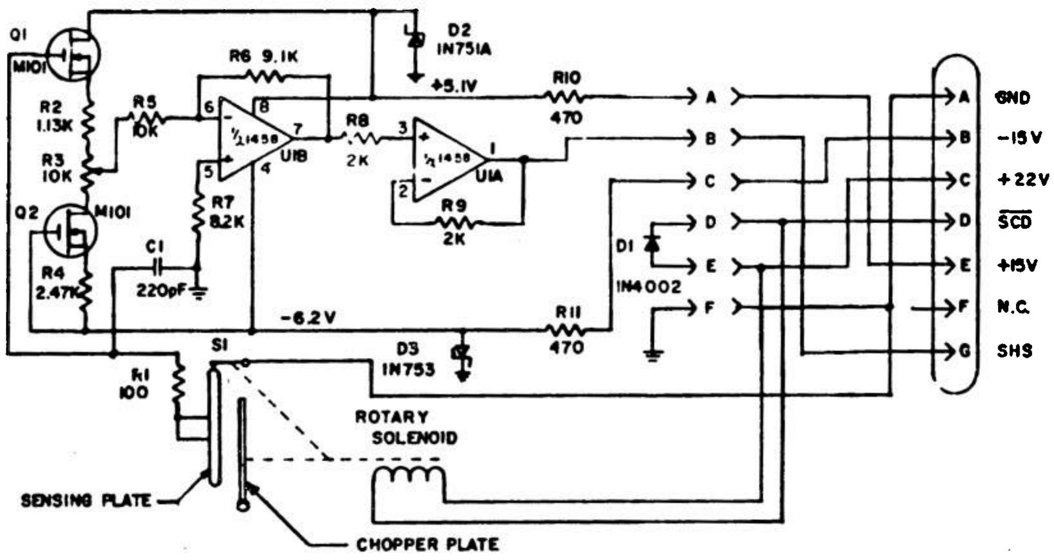
SIZE	CAGE NO	DRAWING NO
C	81337	X4-5-125

SCALE 1/1 | UNIT WT | SHEET 1 OF 1

C X4-5-125

NOTES:

1. MOSFET TRANSISTORS Q1 AND Q2 ARE A MATCHED PAIR.
2. 9.1 K RESISTOR REPLACES ORIGINAL 10 K AS R6 TO COMPENSATE FOR CHANGE IN PHYSICAL POSITION OF SENSOR HEAD IN TEST FIXTURE.



ZONE	LTR	DESCRIPTION	PROJ OFCR	APVD	DATE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
FRACTIONS ±
2 PLACE DIM ±
3 PLACE DIM ±

4-5-121
NEXT ASSY | USED ON
APPLICATION

INTERPRET THIS DRAWING IN ACCORDANCE WITH DOD STD 100

I.K.E. ASSOCIATES, INC.
INDIANAPOLIS, IN 46239
DATE 7/15/87
DRAWN BY Rupe
CHECKED
PROJ OFCR
APPROVED
APPROVAL DESIGN ACTIVITY
APPLICABLE SPEC

U S ARMY NATICK RESEARCH & DEVELOPMENT CENTER
NATICK, MA 01760

SENSOR HEAD SCHEMATIC, MODIFIED DECAY METER

SIZE C | CAGE NO 81337 | DRAWING NO X4-5-126
SCALE NONE | UNIT WT | SHEET 1 OF 1

C X4-5-126

APPENDIX B

DETERMINATION OF ELECTROSTATIC PROPERTIES
OF FABRICS CONTAINING CONDUCTIVE FILAMENTS:
PERCENT FIELD SUPPRESSION

1. SCOPE

1.1 This method is intended for use in measuring the percentage of electrostatic field (E-field) suppression provided in both warp and filling directions by a network of relatively conductive filaments incorporated into an otherwise highly resistive fabric.

1.1.1 The percentage of field suppression reflects the ability of the conductive network in a garment manufactured from the fabric to suppress (when properly grounded) E-fields caused by electrostatic charges present on that garment, on garments worn beneath, or on the person of the user (see 7.1).

1.2 This test may also reveal differences in conductive content between warp and filling directions.

1.3 This test is not applicable to fabrics containing no metal or other highly conductive components.

1.4 This test may be performed in conjunction with FTMS 191, Method BBBB.

2. TEST SPECIMENS

2.1 The specimens shall be taken from a sample of fabric that has had all mill-applied sizing finish removed.

2.1.1 The size of each specimen shall be seven inches long by at least three inches but not more than four inches wide.

2.1.2 The specimens shall be cut so that the long dimension closely parallels either the warp or filling yarns, according to the intended direction of test.

2.1.3 The specimens shall be such that no two specimens shall contain the same set of warp and filling yarns.

2.1.4 Each specimen shall be carefully identified as to source sample unit and whether the direction of test is in the warp or filling direction. Identification marking shall not be within an area of material located between the two electrodes during testing (see 4.2).

3. NUMBER OF DETERMINATIONS

3.1 Unless otherwise specified in the material specification, six specimens, three from each of warp and filling directions shall be tested from each sample unit.

4. APPARATUS

4.1 Static Decay Meter. The meter shall incorporate or be used in conjunction with a noncontacting E-field probe. The instrument shall incorporate a metered HV power supply with an output adjustment range of 0 to at least 5000 V DC. The output current of this power supply shall be internally limited to a maximum of 1 mA at maximum output voltage. The meter shall have an output terminal capable of supplying the detected signal to an external recording device.

In the event the meter has an inordinate amount of "zero" drift with respect to time, it shall incorporate optional automatic zeroing capabilities such that "zero-time" is sufficient to allow full sweep on the Y-axis of the recording device (usually 1 second for chart recorders) and selectable "cycling times" of 3, 6, or 9 seconds. The meter shall also be provided with facilities to inhibit any automatic shutdown provision normally activated when the measured signal decreases past a preset percentage of initial charge value. The meter shall be designed to operate in conjunction with the test fixture described in Para. 4.2 (see 7.4).

4.2 DECAY-TIME TEST FIXTURE. The test fixture shall have been specifically designed for use in performing this test procedure and the procedure described in FTMS 191, Method BBBB. The basic design of the fixture shall be such that the specimen, when mounted, shall be held tautly across two parallel electrodes spaced approximately 3.75 inches apart. The electrodes shall be mounted on a smooth metal plate by means of insulating mounting bolts. The mounting shall be such that the surface of the specimen shall be approximately 0.80 inches from the facing metal plate.

The noncontacting E-field probe (see 4.1.) shall be inserted into the rear of the facing plate such that the measuring end of the probe is flush with the surface of the plate facing the specimen and the measuring orifice of the probe points at the center of the specimen. The plate (with probe mounted) should present a relatively even surface to the specimen to provide as uniform an E-field as possible. The capacitance formed by the specimen and the facing plate shall be XXX pF ±10%. This property can be measured as described in Para. 4.2.1.

The two electrodes shall be electrically connected to each other and to one terminal of a normally open high voltage relay capable of standing off a minimum of 5 kV (DISCHARGE RELAY). The other terminal of this relay shall be connected directly or through the fixture chassis to the facing metal plate. The two electrodes shall also be electrically connected to one terminal of another similar high voltage relay (CHARGE RELAY). The other terminal of this relay shall be connected through a 100 MΩ HV resistor to the HV output of the meter.

HV relay operating circuitry shall be provided in the Static Decay Meter such that when a CHARGE switch is activated, the CHARGE RELAY will close and the DISCHARGE RELAY will open. Activation of a DISCHARGE or TEST switch shall cause first the CHARGE RELAY to open, then after a slight (1 ms) time delay cause the DISCHARGE RELAY to close. Circuitry shall also be provided to make available a user selectable active hi (D5v) or low (0v) "Transistor-to-Transistor Logic" (TTL) trigger signal to the memory of the recording device. Triggering shall occur upon activation of the TEST switch such that the entire signal commencing just before the DISCHARGE RELAY closes is recorded in the memory of the recording device (see 7.4).

4.2.1 A measurement of the capacitance formed by the specimen and the facing plate may be measured as follows if an appropriate capacitance bridge is not available. An insulated sheet metal plate measuring four inches wide and of sufficient height to span the distance between the two electrodes shall be mounted in place of a specimen. Connect a 100 MΩ noninductive resistor between one electrode and the center of the insulated metal plate. This resistor should be on the side of the plate away from the probe. The mounted plate should then be charged to 5 kV DC and then caused to discharge through the resistor and relay while a recording of the discharge curve is made. The RC time constant (τ) of the curve can then be determined.

τ is the time necessary for the curve to decay to 36.8% of some arbitrary voltage amplitude point. The capacitance (C) can then be calculated using the formula $C=\tau/R$, where τ is in seconds, R is the actual measured resistance of the 100 MΩ resistor in Ω, and C is in Farads.

4.3 Recording device. The recording device shall have an incorporated memory or be used in conjunction with a memory to facilitate the acquisition and subsequent display of fast (<1 ms) "one shot" events. The following types of recording devices are suggested.

4.3.1 Storage Oscilloscope. This instrument should have a band width of at least 10 megahertz. An incorporated "plot" output from memory would be beneficial. This would enable the acquisition of immediate "hard copy" of events on an X-Y plotter without resorting to photographic techniques (see 7.5).

4.3.2 Memory chart recorder. This instrument should have the capability of accepting signals from the electrostatic voltmeter, storing them in memory, then reproducing them on an X-Y plot at speeds within the capability of the plotter synchros (see 7.6).

5. PROCEDURE

5.1. Calibration. All electronic instruments shall be powered up for at least 30 minutes prior to calibration. The instrumentation shall then be calibrated as follows.

5.1.1 With the HV power supply in the OFF condition, mount a metal plate of the same width as a specimen between the two electrodes on the test fixture such that the surface of the plate is in the same position as a specimen would assume.

5.1.2 Turn the HV power supply to ON and adjust its output to 5000 V DC. Activate the CHARGE switch thus closing the CHARGE RELAY , applying high voltage to the specimen electrodes. Adjust the static decay meter FULL-SCALE-ADJ control until the sample charge meter indicates an E-field of 5000 Volts. Activate the TEST switch to disable the HV and ground the electrodes. "Zero" the electrostatic voltmeter. Repeat the above operations several times to eliminate interaction between "zero" and "full scale" adjustments. Inhibit any automatic cut off provisions of the meter for the duration of all tests.

5.1.3 With the output of the electrostatic voltmeter connected to the recording instrument, adjust the recorder to indicate "zero" and 5000 volts at convenient points on the Y-axis of the recording media, utilizing the CHARGE and TEST switches as above. Utilize as much of the full width of the recording media as possible.

5.1.4 Activate the TEST switch and remove the metal calibration plate from the test fixture electrodes. Restore the electrodes to the exact condition to be used for specimen testing but WITH NO SPECIMEN MOUNTED. Activate the CHARGE switch to apply 5000 V DC to the electrodes. The voltage now indicated on the electrostatic voltmeter is due to the E-field emanated by the electrodes only. Divide this voltage by 5000 and multiply the result by 100. This final value is the minimum percentage of specimen field suppression the instrumentation is capable of detecting. Record this percentage value for future reference (see Para. 7.3).

5.2 Specimen testing. Actual testing of specimens shall proceed as follows.

5.2.1 With the instrumentation operating and calibrated as above, activate the TEST switch, then mount a specimen across the two electrodes. The specimen shall be so mounted that the intended direction of test (WARP or FILL) is perpendicular to the electrodes. No part of the specimen shall touch any conductive portion of the test fixture other than the electrodes themselves.

5.2.2 Activate the CHARGE switch and observe the approximate length of time necessary for the electrostatic voltmeter to indicate a detected E-field of 5000 Volts. If this takes an inordinate amount of time, specimen can be treated with a weak solution of topical antistat to speed the process without interfering with the results of this test method. (In the event specimen is intended for testing in accordance with FTMS 191, Method BBBB, do not apply this treatment.) Five or six seconds rise time is most convenient.

5.2.3 Set the time base of the recording device such that one full sweep is about 1/10 of the total rise time previously observed.

5.2.4 With the memory of the recording device triggered by the same signal that opens the CHARGE relay, activate the TEST switch.

5.2.5 After the sweep of the recording device has ended, plot the recorded memory. The recording should display an almost vertical line to some point between 5000 Volts and "zero". At that point the line should indicate an abrupt transition and plot a course along the X-axis . This portion of the line should resemble a decaying exponential where the total decay time from the transition point to "zero" would be about equal to the rise time observed earlier (see 7.2).

5.2.6 Determine on the recording media the E-field voltage indicated at the point of transition. Divide this value by 5000 and multiply the result by 100. Subtract that answer from 100 to obtain the percentage of field suppression offered by the conductive content of the specimen. If this percentage value is NOT greater than the value obtained in para. 5.1.4, the conductive content of the specimen can be considered minimal or nonexistent. Record the calculated percentage of field suppression.

5.2.7 Repeat para. 5.2.1 thru 5.2.6 for each of the remaining specimens.

5.2.8 Determine the averages of the percentages obtained for each direction of measurement (warp and fill) and record for reporting purposes.

6. REPORT

6.1 The following information shall be included in the report.

6.1.1 A description of the equipments used. If commercial equipment is used include Manufacturer and Model number for each and a description of special modifications incorporated.

6.1.2 The minimum measurable percentage of field suppression recorded in para. 5.1.4.

6.1.3 A description of the fabric sample from which the specimens were taken.

6.1.4 The average percentages of E-Field suppression calculated in para. 5.2.8. Identify each by direction of test (WARP or FILL). If either is about equal to the value obtained in para. 6.1.2, so state.

7. NOTES

7.1 Conductive filaments consisting of metal or other material woven into an otherwise nonconductive fabric have the effect of suppressing the E-field emanated by any electrostatic charges that might be present on the fabric. This phenomenon is only active when the conductive network is grounded. Further, in the event the relatively nonconductive content of the fabric posesses a modicum of conductivity (semiresistant), the conductive network will enhance the rapid distribution of a charge generated on the fabric. When properly grounded, the conductive network will minimize the length of the resistive path to ground, resulting in a rapid attainment of a net charge of zero volts over the entire unit of fabric.

7.2 Figure 1 is a chart plotted in accordance with this test method. The material tested consisted of a fabric whose basic content was purely synthetic in nature. Each filament in every yarn in the material, however, contained in its core evenly distributed stainless steel particles. The quantity of these particles and the surrounding synthetic material was such that the total content of each filament consisted of 0.50% stainless steel and 99.5% synthetic material. In effect, the entire fabric had the same content. For purposes of this test, the specimen had been treated with a topical antistat to speed up the charging process.

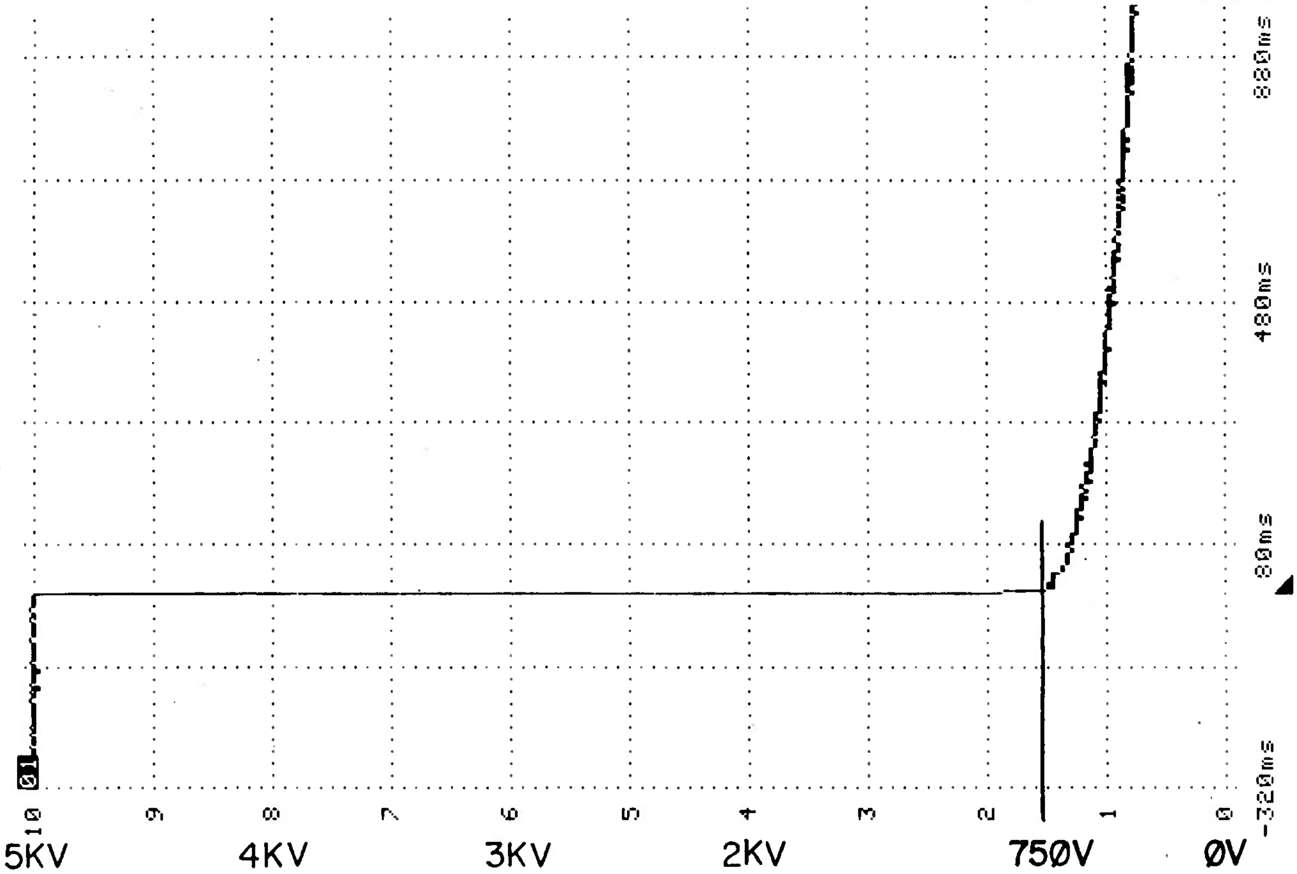
It can be seen that there was an instantaneous suppression of the 5 kV E-field upon closure of the discharge relay. Transition from field suppression to the much slower decay curve occurred at 15% of the original voltage (750 V). This resulted in a field suppression effect of 85%. It should be noted that variations in relative humidity will only affect the charge-up and decay times of the nonconductive content, and not the field suppression percentage.

7.3 It has been found that field suppression effects from all sources are not additive but are superimposed one on the other, with the most effective source predominating. Therefore the field suppression inherent in the test fixture itself will have no effect on the results of this test, provided it is less than that offered by the specimen.

7.4 Electro-Tech Systems, Inc. Model 406C Static Decay Meter with its attendant Decay-time Test Fixture has been found suitable for this application after being modified in accordance with U.S. Army drawings 4-5-120 thru 4-5-126.

7.5 Dynascan Corporation (B&K Precision) Model 2520 Digital Storage Oscilloscope has been found suitable for this application.

7.6 BBC/Metrawatt-Goerz Model SE561 Memory Chart Recorder has been found suitable for this application.

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SE561 / 16k MEMORY / V1.1                              RECORDED: 86 10 29 / 16:22:52
========================

CONTROL UNIT:   SAMPLE TIME   TRIGPOS   TRIG'D   START   LENGTH   ZOOM
------------       200 µs        .5       EXT      .4       .6     .05

STORAGE UNITS:
```

ID	TYP	OVFL	COMMENT	SAMPLE	V/DIV	OUTSP	Z./IN	Z./OUT	TRMOD	TRLEV	ZOOM
1	A16	+-	PR	200 µs	1 V	1	0	0	OFF	0	LIN
2	A16	+		200 µs	.5 V	OFF	0	0	OFF	0	LIN

__FIGURE 1__: FIELD SUPPRESSION CHART--The straight line from 5 kV to 750 V represents the field suppression offered by the conductive content of the fabric when grounded in the direction of test. The curve to the right of 750 V represents the slow charge decay rate of the highly insulative content.

APPENDIX C

DETERMINATION OF ELECTROSTATIC PROPERTIES OF FABRICS WHICH MAY CONTAIN CONDUCTIVE FILAMENTS: ELECTROSTATIC CHARGE DECAY RATE

1. SCOPE

1.1 This method is intended for use in determining the electrostatic charge decay rate of the highly resistive content of a fabric in both warp and filling directions when the fabric may incorporate a network of conductive filaments.

1.1.1 The charge decay rate reflects the ability of the relatively high resistance content in a garment manufactured from the fabric to dissipate (when properly grounded) any electrostatic charges that might occur on the garment. Conductive filaments that may be incorporated serve to speed the decay rate by offering a shorter path to ground (see 7.1).

1.2 This test may also reveal differences in weave between warp and filling directions.

1.3 This test is also applicable to fabrics containing no metal or other highly conductive components.

1.4 This test may be performed in conjunction with FTMS 191, Method AAAA.

2. TEST SPECIMENS

2.1 The specimens shall be taken from a sample of fabric which has had all mill-applied "sizing" finish removed.

2.1.1 The size of each specimen shall be seven inches long by at least three inches but not more than four inches wide.

2.1.2 The specimens shall be cut so that the long dimension closely parallels either the warp or filling yarns, according to the intended direction of test.

2.1.3 The specimens shall be such that no two specimens shall contain the same set of warp and filling yarns.

2.1.4 Each specimen shall be carefully identified as to source sample unit and whether the direction of test is in the warp or filling direction. Identification marking shall not be within an area of material located between the two electrodes during testing (see 4.2).

3. NUMBER OF DETERMINATIONS

3.1 Unless otherwise specified in the material specification, six specimens, three from each warp and filling direction shall be tested from each sample unit.

4. APPARATUS

4.1 Static Decay Meter. The meter shall incorporate or be used in conjunction with a noncontacting E-field probe. The instrument shall incorporate a metered high voltage (HV) power supply with an output adjustment range of 0 to at least 5000 V DC. The output current of this power supply shall be internally limited to a maximum of 1 mA at maximum output voltage. The meter shall have an output terminal capable of supplying the detected signal to an external recording device.

In the event the meter has an inordinate amount of "zero" drift with respect to time, it shall incorporate optional automatic zeroing capabilities such that "zero-time" is sufficient to allow full sweep on the Y-axis of the recording device (usually 1 second for chart recorders) and selectable "cycling times" of 3, 6, or 9 seconds. The meter shall also be provided with facilities to inhibit any automatic shutdown provision normally activated when the measured signal decreases past a preset percentage of initial charge value. The meter shall be designed to operate in conjunction with the test fixture described in Para. 4.2 (see 7.4).

4.2 DECAY-TIME TEST FIXTURE. The test fixture shall have been specifically designed for use in performing this test procedure and the procedure described in FTMS 191, Method AAAA. The basic design of the fixture shall be such that the specimen, when mounted, shall be held tautly across two parallel electrodes spaced approximatly 3.75 inches apart. The electrodes shall be mounted on a smooth metal plate by means of insulating mounting bolts. The mounting shall be such that the surface of the specimen shall be approximately 0.75 inches from the facing metal plate.

The noncontacting E-field probe (see 4.1.) shall be inserted into the rear of the facing plate such that the measuring end of the probe is flush with the surface of the plate facing the specimen and the measuring orifice of the probe points at the center of the specimen. The plate (with probe mounted) should present a relatively even surface to the specimen to provide as uniform an E-field as possible. The capacitance formed by the specimen and the facing plate shall be XXX pF ±10%. This property can be measured as described in Para. 4.2.1.

The two electrodes shall be electrically connected to each other and to one terminal of a normally open HV relay capable of standing off a minimum of 5 kV DC (DISCHARGE RELAY). The other terminal of this relay shall be connected directly or through the fixture chassis to the facing metal plate. The two electrodes shall also be electrically connected to one terminal of another similar HV relay (CHARGE RELAY). The other terminal of this relay shall be connected through a 100 MΩ HV resistor to the HV output of the meter.

HV relay operating circuitry shall be provided in the Static Decay Meter such that when a CHARGE switch is activated the CHARGE RELAY will close and the DISCHARGE RELAY will open. Activation of a DISCHARGE or TEST switch shall cause first the CHARGE RELAY to open, then after a slight (1 ms) time delay cause the DISCHARGE RELAY to close. Circuitry shall also be provided to make available a user selectable active hi (D5v) or low (0v) "Transistor-to-Transistor Logic" (TTL) trigger signal to the memory of the recording device. Triggering shall occur upon activation of the TEST switch such that the entire signal commencing just before the DISCHARGE RELAY closes is recorded in the memory of the recording device (see 7.4).

4.2.1. A measurement of the capacitance formed by the specimen and the facing plate may be measured as follows if an appropriate capacitance bridge is not available. An insulated sheet metal plate measuring four inches wide and of sufficient height to span the distance between the two electrodes shall be mounted in place of a specimen. Connect a 100 MΩ noninductive resistor between one electrode and the center of the insulated metal plate. This resistor shall be on the side of the plate away from the probe. The mounted plate should then be charged to 5 kV DC and then caused to discharge through the resistor and relay while a recording of the discharge curve is made. The RC time constant (τ) of the curve can then be determined.

τ is the time necessary for the curve to decay to 36.8% of some arbitrary voltage amplitude point. The capacitance (C) can then be calculated using the formula $C=\tau/R$, where C is in FARADS, τ is in SECONDS, and R is the actual measured resistance of the 100 Megohm resistor in ohms.

4.3 Recording device. The recording device shall have an incorporated memory or be used in conjunction with a memory to facilitate the acquisition and subsequent display of fast (<1 ms) "one shot" events. The following types of recording devices are suggested.

4.3.1 Storage Oscilloscope. This instrument should have a band width of at least 10 megahertz. An incorporated "plot" output from memory would be beneficial. This would enable the acquisition of immediate "hard copy" of events on an X-Y plotter without resorting to photographic techniques (see 7.5).

4.3.2 Memory chart recorder. This instrument should have the capability of accepting signals from the electrostatic voltmeter, storing them in memory, then reproducing them on an X-Y plot at speeds within the capability of the plotter synchros (see 7.6).

4.4 TEST CHAMBER. A controlled humidity glove box capable of maintaining its internal atmosphere at specified humidity levels (see 7.7).

5. PROCEDURE

5.1. Calibration. All electronic instruments shall be powered up for at least 30 minutes prior to calibration. The instrumentation shall then be calibrated as follows.

5.1.1 With the HV power supply in the OFF condition, mount an uninsulated metal plate of the same width as a specimen between the two electrodes on the test fixture such that the surface of the plate is in the same position as a specimen would assume.

5.1.2 Turn the HV power supply to ON and adjust its output to 5000 volts. Activate the CHARGE switch thus closing the CHARGE RELAY , applying high voltage to the specimen electrodes. Adjust the decay meter FULL-SCALE-ADJ control until the sample charge meter indicates an E-field of 5000 volts.

Activate the TEST switch to disable the HV and ground the electrodes. "Zero" the electrostatic voltmeter. Repeat the above operations several times to eliminate interaction between "zero" and 5000 volt adjustments. Inhibit any automatic cut-off provisions of the meter for the duration of all tests.

5.1.3 With the output of the electrostatic voltmeter connected to the recording instrument, adjust the recorder to indicate "zero" and 5000 volts at convenient points on the Y-axis of the recording media, utilizing the CHARGE and TEST switches as above. Utilize as much of the full width of the recording media as possible.

5.1.4 Activate the TEST switch and remove the metal calibration plate from the test fixture electrodes. Restore the electrodes to the exact condition to be used for specimen testing but WITH NO SPECIMEN MOUNTED. Activate the CHARGE switch to apply 5000 V DC to the electrodes. The voltage now indicated on the electrostatic voltmeter is due to the E-field emanated by the electrodes only. Divide this voltage by 5000 and multiply the result by 100. This final value is the minimum percentage of field suppression the instrumentation is capable of detecting. Record this percentage value for future reference (see 7.3).

5.2 Specimen Conditioning and Testing. Conditioning and testing of specimens shall proceed as follows.

5.2.1 In the event a specific humidity level is required for the test, all test specimens together with the test fixture shall have been conditioned within the controlled humidity chamber at the specified RH level for a minimum of six hours. This RH level shall be maintained until all tests have been completed.

5.2.2 With the instrumentation operating and calibrated as above, activate the TEST switch, then mount a specimen across the two electrodes. The specimen shall be so mounted that the intended direction of test (WARP or FILL) is perpendicular to the electrodes. No part of the specimen shall touch any conductive portion of the test fixture other than the electrodes themselves.

5.2.3 Activate the CHARGE switch and observe the approximate length of time necessary for the electrostatic voltmeter to indicate a detected E-field of 5000 volts. If this takes longer than about three minutes, terminate this test as impractical.

5.2.4 Set the time base of the recording device such that one full sweep is about 1/10 of the total rise time previously observed.

5.2.5 With the memory of the recording device triggered by the same signal that opens the CHARGE relay, activate the TEST switch.

5.2.6 After the sweep of the recording device has ended, chart the recorded memory. The recording should display an almost vertical line to some point between 5000 volts and "zero". At that point the line should indicate an abrupt transition and plot a course along the X-axis. This portion of the line should resemble a decaying exponential where the total decay time from the transition point to "zero" would be about equal to the rise time observed earlier (see 7.2).

5.2.7 Determine on the recording media the E-field voltage indicated at the point of transition. Divide this value by 5000 and multiply the result by 100. Subtract that answer from 100 to obtain the percentage of field suppression offered by the conductive content of the specimen. If this percentage value is NOT greater than the value obtained in Para. 5.1.4, the conductive content of the specimen can be considered minimal or nonexistent. Record the calculated percentage of field suppression (see 7.3).

5.2.8 If the percentage of field supression indicates a significant conductive content, adjust the recording instrument Y-axis voltage sensitivity level such that the instrument will be "over-driven" to the extent that the transition point determined in 5.2.7 will be as near as convenient but not beyond the maximum of the Y-axis.

5.2.9 Set the time base of the instrument such that the length of the sweep will include at least that portion of the decay curve wherein the measured value decreases to 36.8% of the value indicated at the transition point.

5.2.10 Activate the "CHARGE" relay and allow the specimen to attain full charge (5000 V). Activate the TEST switch, using the same signal to trigger the recording instrument. The decay curve of the relatively nonconductive portion of the specimen will thus be recorded.

5.2.11 From the recorded curve determine the time required for the detected voltage to decay from the transition point (or nearest convenient later point) to 36.8% of the selected Y-axis value. Actual voltage values are irrelevant. Y-axis graduations of the recording media may be used. This time span is the "DECAY-RATE" (τ) of the nonconductive content of the material under test. Record this decay rate and the humidity level at the time of test.

5.2.12 Repeat para. 5.2.1 thru 5.2.11 for each of the remaining specimens.

5.2.13 Determine the averages of the decay rates and test RH levels for each direction of measurement (WARP and FILL). Multiply the average decay rates (τ) by 5 (5τ). Record the τ and 5τ values and the average test RH levels for reporting purposes.

6. Report

6.1 The following information shall be included in the report.

6.1.1 A description of the equipments used. If commercial equipment is used include Manufacturer and Model number for each and a brief description of special modifications incorporated.

6.1.2 The minimum measurable percentage of field suppression recorded in para. 5.1.4

6.1.3 The average test RH levels and decay time values determined in para. 5.2.13. Identify by direction of test (WARP or FILL).

7. NOTES

7.1 Conductive filaments consisting of metal or other material woven into an otherwise nonconductive fabric have the effect of suppressing the E-field emanated by any electrostatic charges that might be present on the fabric. This phenomenon is only active when the conductive network is grounded. Further, in the event the relatively nonconductive content of the fabric posesses a modicum of conductivity (semiresistant), the conductive network will enhance the rapid distribution of a charge generated on the fabric. When properly grounded, the conductive network will minimize the length of the resistive path to ground, resulting in a rapid attainment of a "net charge" of zero volts over the entire unit of fabric.

7.2 Figures 1 and 2 are charts plotted in accordance with this test method. The material tested consisted of a fabric whose basic content was purely synthetic in nature. However, each filament in every yarn in the material, contained in its core evenly distributed stainless steel particles. The quantity of these particles and of the surrounding synthetic material was such that the total content of each filament consisted of 0.50% stainless steel and 95.5% synthetic material. In effect, the entire fabric had the same content.

For purposes of these illustrations, the specimen had been sprayed lightly with a topical antistat to speed up the charge and discharge processes. Fabric with no topical antistat applied could have a much slower decay rate depending on the nature of the basic material and the RH level at the time of test. The specimen was first tested with the recorder memory set for an indication of 500 volts of specimen charge per major division on the Y-axis for figure 1. The recorder sensitivity was then increased to yield an indication of 50 volts per division and the test performed again for figure 2.

It can be seen from figure 1 that there was an instantaneous suppression of the 5 KV E-field upon closure of the discharge relay. Transition from field suppression to the much slower decay curve occurred at 10% of the original voltage (500 V). This resulted in a field suppression effect of 90%. Note that variations in relative humidity will only affect the charge-up and decay times of the nonconductive content, and not the field suppression percentage.

Figure 2 illustrates how the voltage at the transition point of figure 1 was translated to a point much higher (X10) on the Y-axis. That level (10) was then multiplied by .368 to determine the point on the curve where the E-field had decayed to 36.8% of its value at maximum field suppression. The elapsed time of 17.5 seconds between the two points is then the "DECAY-RATE" (τ) of the relatively nonconductive content of the specimen.

Note that although 5τ is generally considered the theoretical time to "zero" for a decaying exponential, it has been found that certain high-order polymers do not exactly follow Ohm's Law. Essentially, the resistivity of the material may be inversely proportional to the voltage applied. If Ohm's Law was exactly applicable in this case, the curve would arrive at "zero" at 87.5 seconds (5τ).

However, if 7 is used as the initial level, 36.8% of 7 is 2.6 and results in the considerably slower decay rate of 29.75 seconds. This is a direct result of the nature of the synthetics involved. It is essential, therefore, to determine the transition point with maximum accuracy for the sake of consistency in calculations. In the event a number of different fabrics of varying conductive content are being tested for comparison purposes, it is advisable to determine the transition point of that fabric offering maximum suppression and use that value in calculations for all in the interests of accuracy.

7.3 It has been found that field suppression effects from all sources are not additive but are superimposed one on the other, with the most effective source predominating. The field suppression inherent in either the test fixture itself or in the specimen will have no effect on the results of this test provided calculations for τ are based on the actual transition point of the curve.

7.4 Electro-Tech Systems, Inc. Model 406C Static Decay Meter and its attendant Decay-time Test Fixture has been found suitable for this application after being modified in accordance with U.S. Army drawings 81337-X4-5-120 thru 81337-X4-5-126.

7.5 Dynascan Corporation (B&K Precision) Model 2520 Digital Storage Oscilloscope has been found suitable for this application.

7.6 BBC/Metrawatt-Goerz Model SE561 Memory Chart Recorder has been found suitable for this application.

7.7 Electro-Tech Systems, Inc. Model 506 Humidity test chamber has been found suitable for this application.

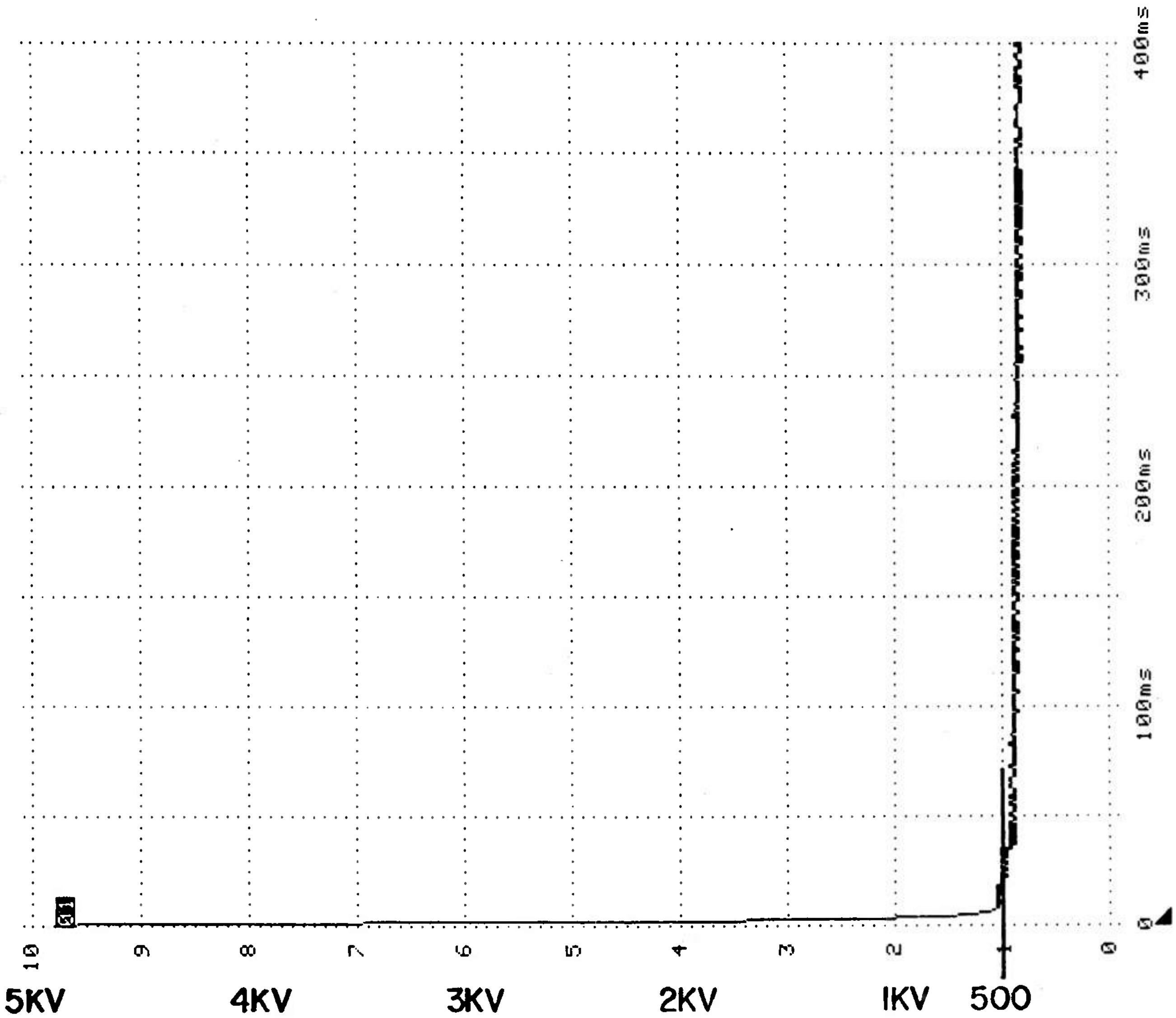


FIGURE 1: FIELD SUPPRESSION CHART--The straight line from 5 kV to 500 V represents the field suppression offered by the conductive content of the fabric when grounded in the direction of test. The curve to the right of 500 V represents the slow charge decay rate of the highly insulative content.

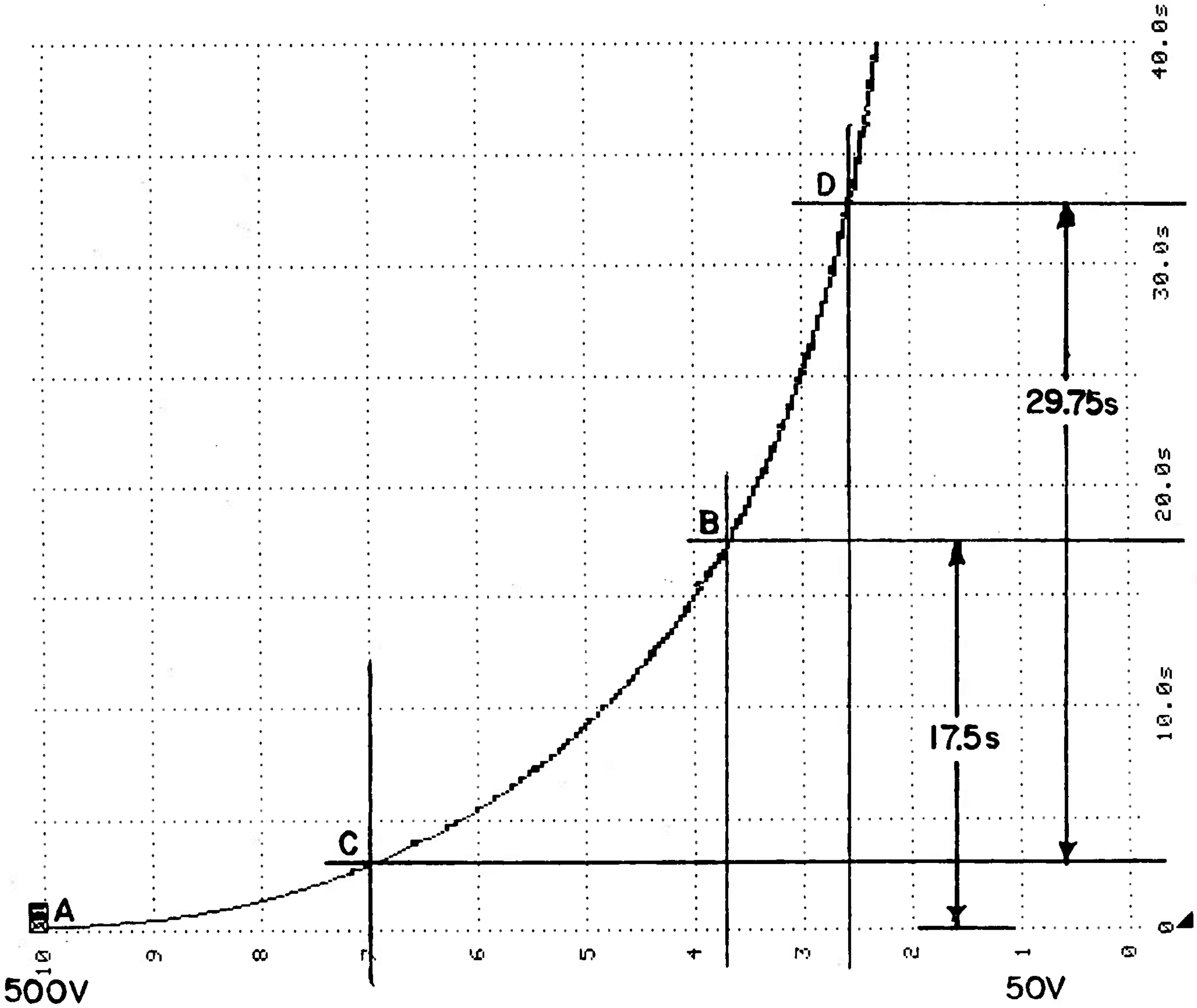


FIGURE 2: DECAY RATE CHART--The time required for the curve to decay from point A to point B is the decay rate (17.5 s) of the nonconductive content of the fabric. The time between "C" and"D" (29.75 s) results from a lower commencing voltage and illustrates the nonohmic nature of the material.

APPENDIX D

DETERMINATION OF ELECTROSTATIC PROPERTIES OF FABRICS: TRIBOELECTRIC CHARGE GENERATION

1. SCOPE

1.1 This method is intended for use in determining the charge developed on a specimen of fabric when rubbed with another material, in this case Teflon(R). No distinction is made between warp and filling directions of the fabric, nor is the presence or absence of conductive content in the specimen considered a contributing factor. Differences in surface textures (smooth or rough) between one side of the specimen and the other may, however, result in charge amplitude variations. This test may also be used for flexible materials other than fabrics up to 1/16 inch in thickness.

1.2 The electrostatic charges detected during the course of this test reflect the ability of the material under test to resist the generation of electrostatic charges when rubbed with and separated from itself or another material (see 7.1).

1.3 This test is also useful in determining the efficacy of a topical antistatic treatment intended for use on garments or other items when such treatment is intended to inhibit the triboelectric generation of electrostatic charges.

2. TEST SPECIMENS

2.1 The specimens shall be taken from a sample of fabric which has had all mill-applied sizing finish removed. In the event the test is intended to determine the efficacy of an antistatic treatment, the sample shall then have been treated with the topical antistat in accordance with normal garment treatment procedures.

2.2 The size of each specimen shall be at least 7 inches square prior to mounting in the sample holder. After each specimen has been clamped tautly in its holder, all protruding edges of the specimen shall be carefully trimmed flush with the outer edges of the holder. No identification marking by ink or any other foreign substance is permitted on that portion of the specimen visible in the opening of the sample holder.

2.3 The specimens shall be such that no two specimens shall contain the same set of warp and filling yarns.

2.4 Each sample holder shall be carefully identified or coded as to its contained specimen.

3. NUMBER OF DETERMINATIONS

3.1 Unless otherwise specified in the material specification, three specimens shall be tested from each sample unit.

4. APPARATUS

4.1 The test apparatus shall consist of the following equipments:

4.1.1 A Triboelectric Test Fixture manufactured in accordance with U S Army Drawing Nos. 81337-X 4-5-100 thru 81337-X4-5-118. At least ten (10) specimen frame assemblies per 81337-X4-5-106 are recommended (see 7.3).

4.1.2 An Electro-Tech Systems, Inc. Model 406C Static Decay Meter modified in accordance with U S Army Drawing No. 81337-X4-5-120 to operate in conjunction with the test fixture described in 4.1.1. In the event the meter has an inordinate amount of "zero" drift with respect to time, it shall incorporate optional automatic zeroing capabilities such that "zero-time" is sufficient to allow full sweep on the Y-axis of the recording device (>1 sec) and selectable "cycling times" of 3, 6, and 9 seconds. The "TEST" switch of the Decay Meter will not be used during this procedure (see 7.4).

4.1.3 A recording device such as a storage oscilloscope or a chart recorder (see 7.5, 7.6).

4.1.4 A controlled humidity glove box capable of maintaining its internal atmosphere at specified humidity levels (see 7.7).

5. PROCEDURE

5.1 Calibration. All units necessary for this test method shall be connected as indicated in U S Army Drawing No 81337-X4-5-119 and powered up for at least 30 minutes prior to calibration. The instrumentation shall then be calibrated as follows.

5.1.1 Mount the calibration plate in the test fixture with the hollowed-out side facing away from the rubbing wheel. Attach the HV lead from the Decay Meter to the plate at the "banana-jack" hole located in its edge.

5.1.2 Turn on the "charging voltage" of the Decay Meter and adjust for 5 kV output. Zero the sample charge meter. Press the CHARGE button and set the FULL-SCALE-ADJ control for a reading of 1 kV on the sample charge meter. Repeat "zero" and "full-scale" adjustments several times to minimize interaction. Set the automatic Zero provision of the meter (if available) for a 6 second cycle. Make sure that zero and full-scale adjustments remain as before.

5.1.3 Attach the recording device to the recorder output of the Decay Meter. A high impedance digital voltmeter connected in parallel with the recording device will afford greater accuracy in adjustments. An indication of 1 kV at the sample charge meter should yield 2.0 VDC at the recorder output. Adjust the recording device such that "zero" is at the center of the Y-axis of the recording media and the peak input voltage level is located 1/5 of the distance to the edge. By this means the instrumentation will be capable of measuring and recording up to a 25 kV charge of either polarity as detected by the probe. If a chart recorder is used, 10 divisions will allow 5 kV per division with a full range from +25 to -25 kV (50 kV total). This is the full capability of the Decay Meter when used in conjunction with the specified E-field probe which forms a part of the test fixture.

5.1.4 Disable the HV supply and remove the calibration plate from the test fixture.

5.2 Specimen Conditioning and Testing

5.2.1 In the event a specific humidity level is required for the test, all test specimens together with the test fixture shall have been conditioned within the controlled humidity chamber at the specified RH level for a minimum of six hours. This RH level shall be maintained until all tests have been completed (see 7.7).

5.2.2 Perform the calibration procedure in accordance with Para. 5.1.

5.2.3 Apply power to the Test Fixture motor. The rubbing wheel will commence rotating at exactly 100 RPM. With a clean tissue moistened with a suitable solvent clean the rubbing surface of the wheel and allow to dry. Trichloroethylene fumes have been found to have minimal adverse effects on humidity indicating devices. The wheel must be recleaned prior to each specimen test.

5.2.4 Insert a specimen frame (loaded with a specimen) into the test fixture with the desired test surface of the specimen facing the rubbing wheel.

5.2.5 Depress the CHARGE switch on the Decay Meter. Be sure the HV supply is OFF. With the recording device so connected as to be triggered by initiation of rubbing time and adjusted to record for 30 seconds minimum, press the RUN switch on the test fixture. The rotating rubbing wheel will move forward against the specimen, remain there for exactly ten seconds, and then return to its original position. The E-field from the specimen and frame will be recorded and will appear as a decaying exponential due to the bleed-off of the charge from specimen to frame and/or corona discharge from sharp edges or corners of specimen and frame.

About 8 or 9 seconds after the wheel has retracted, remove the specimen frame from the Test Fixture. Press the RUN switch immediately to return the rotating wheel to the rubbing position WITH NO SPECIMEN FRAME IN PLACE. The wheel will remain in that position for ten seconds and then retract. The E-Field detected on the rubbing wheel will thus be recorded. This field will be of opposite polarity to that previously detected on the specimen and will be recorded as a flat line due to the highly insulative nature of the rubbing wheel. In the event automatic zeroing is used during this test, the peak specimen charge may be lost during a "zero" interval. However, the recorded rubbing wheel charge is proportional to the peak specimen charge, but of opposite polarity (see 7.1).

5.2.6 If a Chart Recorder has been used, identify the recording as to specimen description, calibrated detected Y-axis voltage per division, and other pertinent information (e.g. which specimen surface was rubbed, humidity, etc.). If a Storage Oscilloscope was used, determine the specimen peak charge voltage and the wheel charge voltage. Write these values down together with the specimen description and other pertinent information.

5.2.7 Clean the wheel with solvent as before, then repeat, commencing with Para. 5.2.4 for the next specimen.

5.2.8 After all specimens have been tested, average the wheel charge measurements obtained from all specimens from each sample unit and record for reporting purposes (see 7.2).

6. REPORT

6.1 The following information shall be included in the report.

6.1.1 A description of equipments used. If commercial equipment is used include manufacturer and Model number for each and a description of special modifications incorporated.

6.1.2 Identify each specimen by sample description and which side was tested (if pertinent).

6.1.3 The relative humidity of the test environment at the time of test.

6.1.4 The average post-test charge voltage detected on the wheel while in rubbing position with no specimen in place.

7. NOTES

7.1 Triboelectric charging is the result of an exchange of electrons, which occurs when two materials in close contact with each other are suddenly separated. Rubbing the two materials together can be considered multiple contacts and separations. One material loses electrons and evidences a positive charge while the other gains electrons and becomes negatively charged. Since the rubbing media of the test fixture is at the extreme lower end of the "Triboelectric Series", it will always acquire a negative charge unless the specimen is of the same material. Unless the wheel is cleaned with a solvent after each test, its surface may soon become contaminated by the specimen material, possibly resulting in a reversal of polarities. This is due to the rubbing surface of the wheel gradually becoming essentially the same material as the specimen.

Due to the highly insulative nature of the rubbing media, any charge placed on its surface will remain immobile (static) for long periods of time. Since the electrons that caused this charge were acquired from the specimen only, it is always directly related to the peak charge that was generated on the specimen.

The indicated "wheel charge" is usually less than any indicated peak "specimen charge" due to the field supression effect of the grounded metal disk on which the rubbing media is mounted. The one exception to this is when the specimen is so conductive as to allow its charge to bleed off to the specimen frame more rapidly than the instrumentation is capable of recording.

7.2 Figures 1, 2, and 3 are example charts plotted while testing (in accordance with this test method) a specimen of Nomex(R)/Kevlar(R) basic fabric containing 1% of silver-coated Nylon(R) filaments in every yarn. The relative humidity was 48%. Figures 1 and 2 were recorded simultaneously with figure 2 at twice the sensitivity for clarification. Note that the automatic zeroing feature of the instrumentation was not used.

In figure 1, section A of the curve is the time spent in rubbing. At point B the wheel retracts from the specimen which then indicates a peak charge. Section C is the interval where the specimen charge is being measured. The sharp drop past "zero" at point D indicates the action of removing the specimen and exposing the wheel to the E-field probe. Section E is the interval during which the wheel is in its retracted position with no specimen in place. At point F the RUN switch is pressed again to return the wheel to its rubbing position. Section G is the period where the wheel is in the rubbing position with no specimen in place. Observe that the plot indicates a peak specimen charge of + 3.0 kV and that a residual wheel charge of -4.75 kV in the advanced position is indicated. The smaller peak specimen charge is due to the rather rapid dissipation of instantaneous peak charge at the moment of separation caused by the conductive content of the specimen.

Figure 3 was plotted a few moments later while using a 6-second automatic zero cycle. A recorder sensitivity of 2.5 kV per division was used. Note that the actual peak specimen charge was lost during a zero interval. The unsynchronized occurrence of wheel retraction due to operator initiation of rubbing time and the possible presence of conductive content in the fabric therefore dictates that the residual charge on the wheel is of prime interest, at least in all cases where automatic zeroing is utilized and/or the specimen has conductive content.

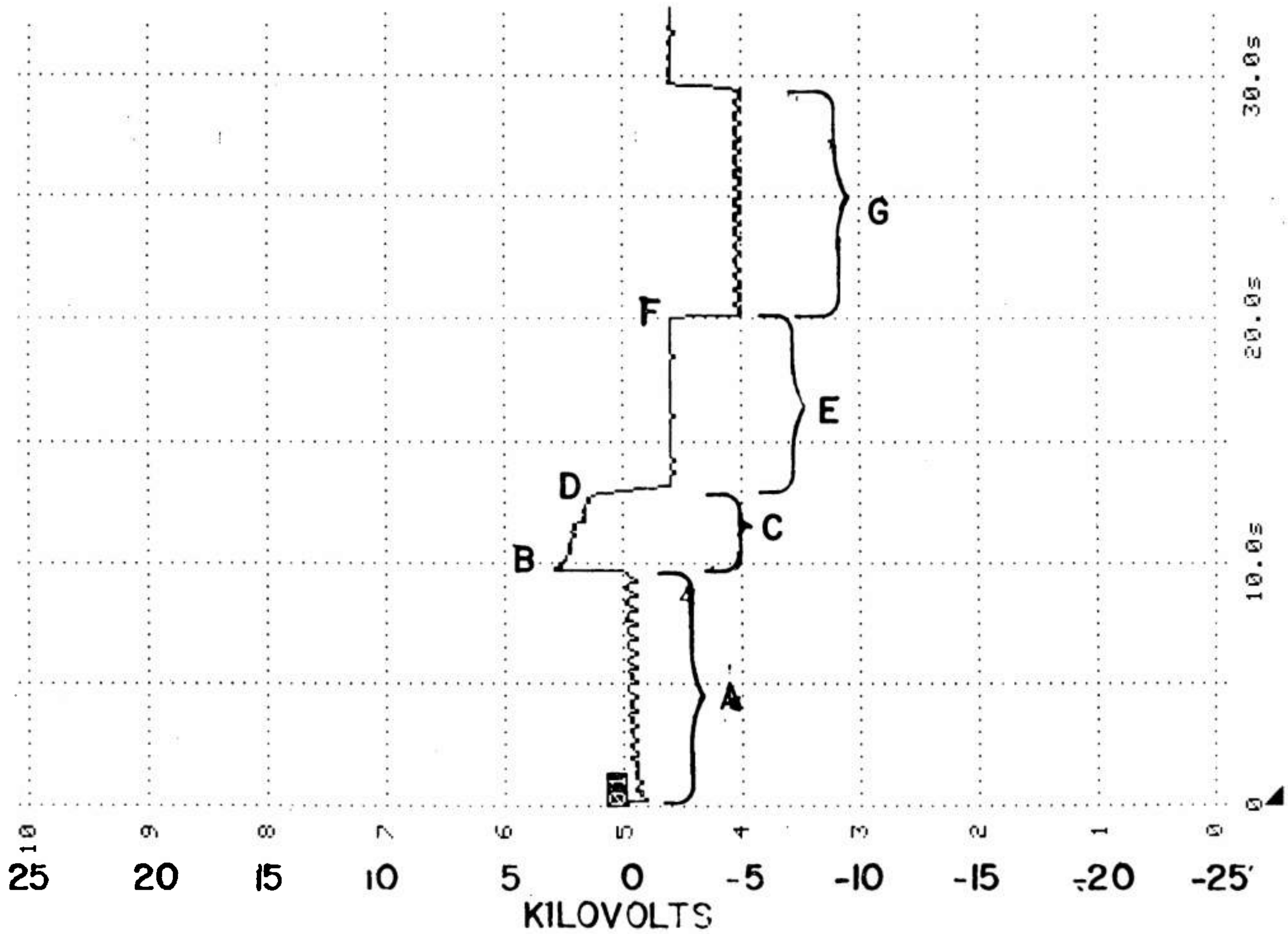
7.3 Electro-Tech Systems, Inc. Model 407 Triboelectric Test Fixture has been found suitable for this application.

7.4 Electro-Tech Systems, Inc. Model 406C Static Decay Meter has been found suitable for this application after being modified as necessary to operate in conjunction with the Test Fixture described in Para. 7.3.

7.5 Dynascan Corporation (B&K Precision) Model 2520 Digital Storage Oscilloscope has been found suitable for this application.

7.6 BBC/Metrawatt-Goerz Model SE561 Memory Chart Recorder has been found suitable for this application.

7.7 Electro-Tech Systems, Inc. Model 506 Humidity test chamber has been found suitable for this application.



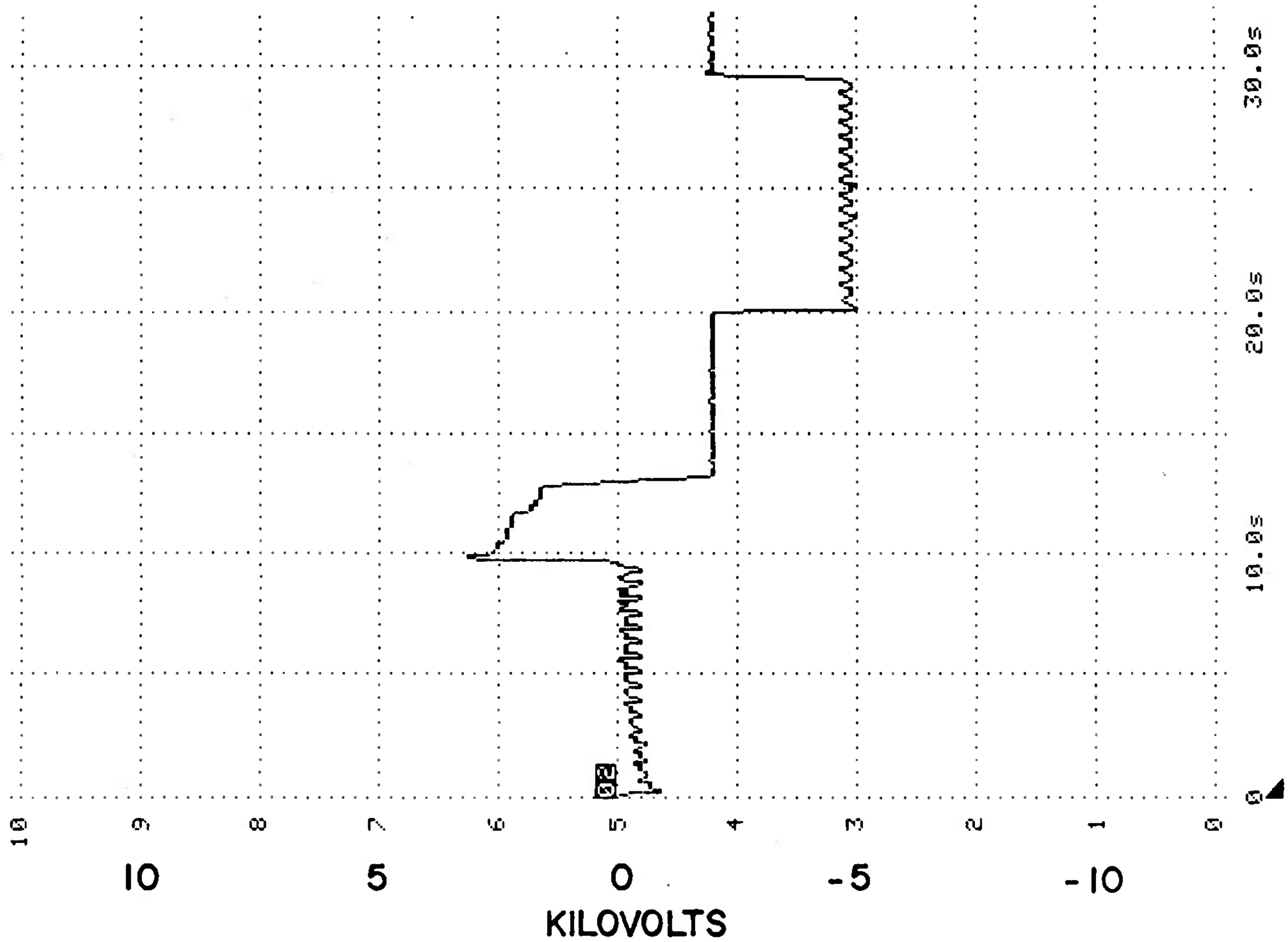
SE561 / 16k MEMORY / V1.1 RECORDED: 87 08 04 / 11:47:46

CONTROL UNIT:	SAMPLE TIME	TRIGPOS	TRIG'D	START	LENGTH	ZOOM
	5 ms	.5	EXT	.5	.5	.05

STORAGE UNITS:

ID	TYP	OVFL	COMMENT	SAMPLE	V/DIV	OUTSP	Z./IN	Z./OUT	TRMOD	TRLEV	ZOOM
1	A16		PR	5 ms	2 V	1	5	5	OFF	0	LIN
2	A16			5 ms	1 V	OFF	5	5	OFF	0	LIN

FIGURE 1: TRIBOELECTRIC TEST CHART--An example chart recorded during testing of a fabric. No automatic zero action. Refer to Para. 7.2 for explanatory text.



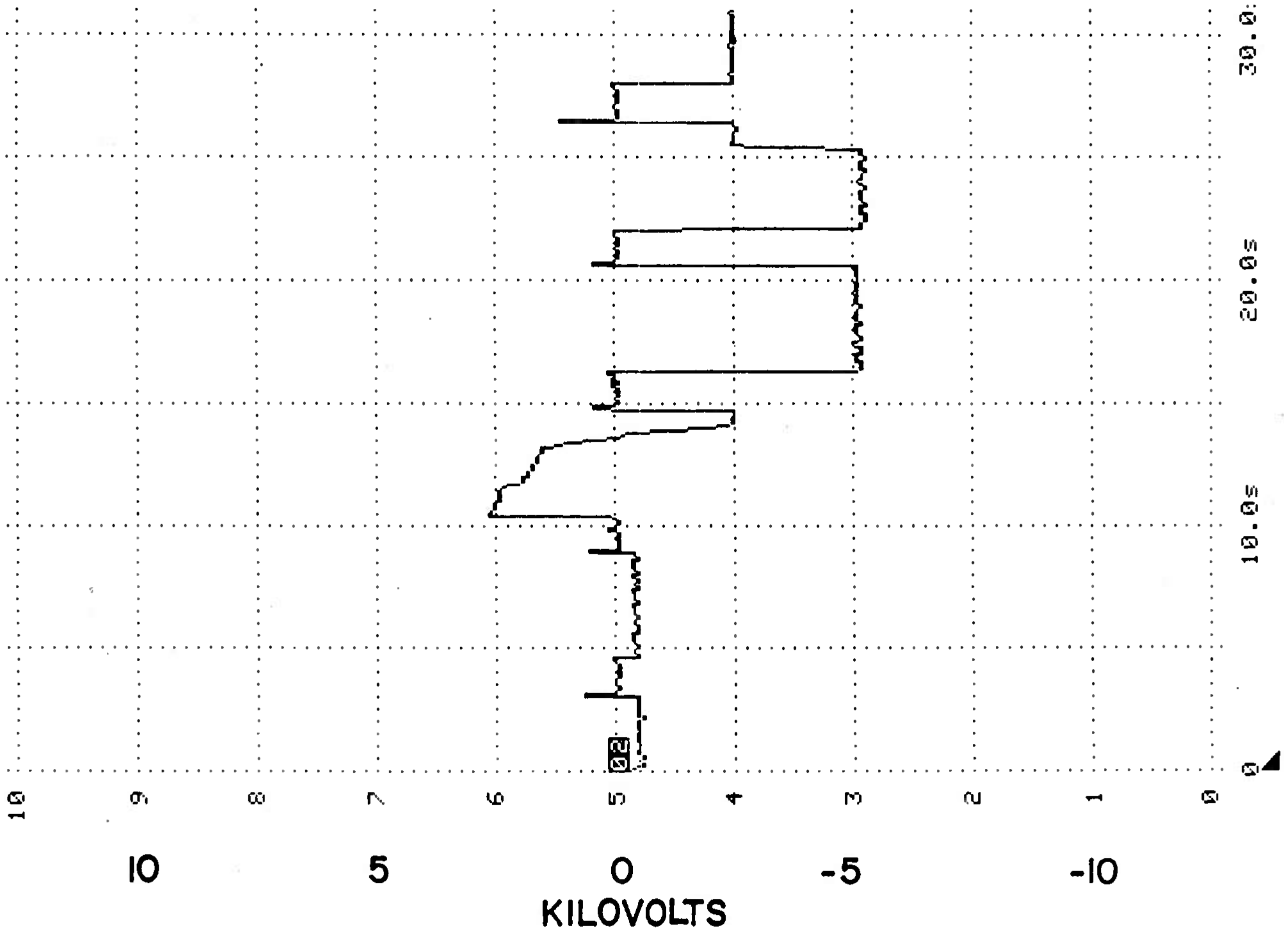
SE561 / 16k MEMORY / V1.1 RECORDED: 87 08 04 / 11:47:46

CONTROL UNIT:	SAMPLE TIME	TRIGPOS	TRIG'D	START	LENGTH	ZOOM
	5 ms	.5	EXT	.5	.5	.05

STORAGE UNITS:

ID	TYP	OVFL	COMMENT	SAMPLE	V/DIV	OUTSP	Z./IN	Z./OUT	TRMOD	TRLEV	ZOOM
1	A16			5 ms	2 V	OFF	5	5	OFF	0	LIN
2	A16		PR	5 ms	1 V	1	5	5	OFF	0	LIN

FIGURE 2: TRIBOELECTRIC TEST CHART--Same as figure 1 except twice the voltage sensitivity. Refer to Para. 7.2 for explanatory text.



SE561 / 16k MEMORY / V1.1

RECORDED: 87 08 04 / 11:53:27

CONTROL UNIT:	SAMPLE TIME	TRIGPOS	TRIG'D	START	LENGTH	ZOOM
	5 ms	.5	EXT	.5	.5	.05

STORAGE UNITS:

ID	TYP	OVFL	COMMENT	SAMPLE	V/DIV	OUTSP	Z./IN	Z./OUT	TRMOD	TRLEV	ZOOM
1	A16			5 ms	2 V	OFF	5	5	OFF	0	LIN
2	A16		PR	5 ms	1 V	1	5	5	OFF	0	LIN

<u>FIGURE 3</u>: TRIBOELECTRIC TEST CHART--This chart was recorded with 6 second "Auto-zero" activated. Refer to Para. 7.2 for explanatory text.

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